NASA Technical Memorandum TM 107562

Debris/Ice/TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-57

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National Aeronautics and Space Administration

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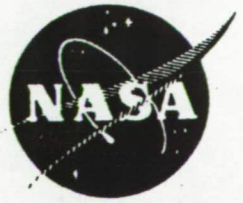

DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-57

June 21, 1993

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FOREWORD

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

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

ORIGINAL PAGE
COLOR PHOTOGRAPH

Shuttle Mission STS-57 was launched at 9:07 a.m. local 6/21/93

1.0 Summary

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 19 June 1993. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (4th flight), ET-58 (LWT 51), and BI-059 SRB's. There were no vehicle anomalies.

The vehicle was cryoloaded for flight on 20 June 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. The External Tank exhibited light condensate on the TPS acreage. The LH2 ET/ORB umbilical leak sensor detected no significant hydrogen leakage during the cryoload. No unusual vapors or cryogenic drips were visible during tanking, stable replenish, and launch.

The launch was scrubbed at T-5 minutes (and holding) due to RTLS and TAL weather. A post drain inspection of the vehicle revealed no significant anomalies and the ET appeared ready for the next cryoload.

A repeat of the pre-launch debris inspection had not been planned since the MLP deck was subject to controlled access.

The vehicle was cryoloaded a second time on 21 June 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. The External Tank exhibited light condensate on the TPS acreage. No unusual vapors or cryogenic drips were visible during tanking, stable replenish, and launch.

After the 9:07 a.m. launch on 21 June 1993, a debris inspection of Pad 39A was performed. No flight hardware or TPS materials were found with the exception of a frangible nut web on the stud in holddown post (HDP) #2. EPON shim material on the south holddown posts was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. Damage to the facility overall was minimal.

A total of 133 films and videos were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. No stud hang-ups occurred on any of the holddown posts. Two frangible nut pieces fell from the HDP #2 DCS/stud hole after liftoff. All T-0 umbilicals operated properly.

On-orbit imagery, ET/ORB umbilical cameras and the flight crew handheld photography, revealed nominal SRB and ET separations. The lightning contact strip was missing from the top of the LO2 ET/ORB umbilical (the others were intact). TPS damage had occurred on the top inboard section of the umbilical.

The red purge seal was missing from the LH2 ET/ORB umbilical near the 4-inch disconnect (still attached to the Orbiter after landing) and at the top outboard section. A piece of white RTV drifting by the camera lens may also have originated from the top outboard section. TPS damage had occurred on the inboard side of the umbilical and a large piece of foam, which measured approximately 2 feet long by 4 inches wide by as much as 1 inch thick, had partially separated from the umbilical. TPS on the top surface of the umbilical had peeled back in two places.

At least 70 divots, 3-4 inches in diameter, occurred on the intertank stringer heads forward of the bipods. Seven small divots were visible in the LH2 tank-to-intertank flange closeout between the bipods. Both +Y and -Y bipod ramps and jack pad closeouts were intact. Nine divots, 6-8 inches in diameter, occurred along a line on the -Y thrust panel on the +Z side of the EB fitting. Nine smaller divots were scattered on the -Y thrust panel on the -Z side of the EB fitting.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The RH frustum had 46 MSA-2 debonds over fasteners and two areas of missing MSA-2. The LH frustum was missing no TPS, but had 27 MSA-2 debonds over fasteners. All eight Debris Containment System (DCS) plungers were seated. No malfunction of the HDP #2 DCS was apparent even though two frangible nut pieces had fallen from the stud hole after liftoff (as observed in the film review).

A post landing inspection of OV-105 was conducted after the landing at KSC. The Orbiter TPS sustained a total of 106 hits, of which 12 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 75 hits, of which 10 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of debris hits and the number of hits one inch or larger was less than average. ET/Orbiter separation devices EO-1 and EO-3 appeared to have functioned properly. The EO-2 debris plunger was obstructed by ordnance fragments.

A 15-inch long piece of foam with red purge seal, which should have remained with the ET during separation, adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve. A 3" x 1" piece of ET foam adhered to a tile on the RH ET door near the hinge line. The foam had been compressed into the thermal barrier when the door was closed, but apparently did not affect the seal.

A 7/16" x 3/32" screw from the purge barrier retainer lay on the runway below the LH2 ET/ORB umbilical cavity. A nutplate with threads matching the screw was found wedged in a cavity on the ET door.

A walkdown of KSC Runway 33 was performed immediately after landing. No debris or unexpected flight hardware was found. All drag chute hardware was recovered and appeared to be in good condition.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from sources such as Orbiter TPS, SRB BSM exhaust residue, window covers and processing, natural landing site products, organics, and paint. These residual sampling data do not indicate a single source of damaging debris since no damage has been associated with the sampled material. Additionally, most of the observed materials have previously been documented in post-landing sample reports. The residual sample data also showed no debris trends when compared to previous mission data.

A total of 17 Post Launch Anomalies, including six IFA candidates, were observed during the STS-57 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Debris/TPS/Photographic Analysis Team briefing for launch activities was conducted on 18 June 1993 at 1430 hours with the following key personnel present:

B. Davis	NASA - KSC	STI, Ice/Debris Assessment
G. Katnik	NASA - KSC	Lead, Ice/Debris/Photo Team
B. Speece	NASA - KSC	Lead, ET Thermal Protection
B. Bowen	NASA - KSC	ET Processing, Ice/Debris
K. Tenbusch	NASA - KSC	ET Processing, Ice/Debris
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
J. Rivera	NASA - KSC	Lead, ET Structures
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
J. Cawby	LSOC - SPC	Supervisor, ET Processing
M. Jaime	LSOC - SPC	ET Processing
W. Richards	LSOC - SPC	ET Processing
J. McClymonds	RI - DNY	Debris Assess, LVL II Integ
W. Atkinson	RI - LSS	Vehicle Integration
R. Hillard	MTI - LSS	SRM Processing
M. Nowling	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing
D. Maxwell	LSOC - SPC	Safety

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

2.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

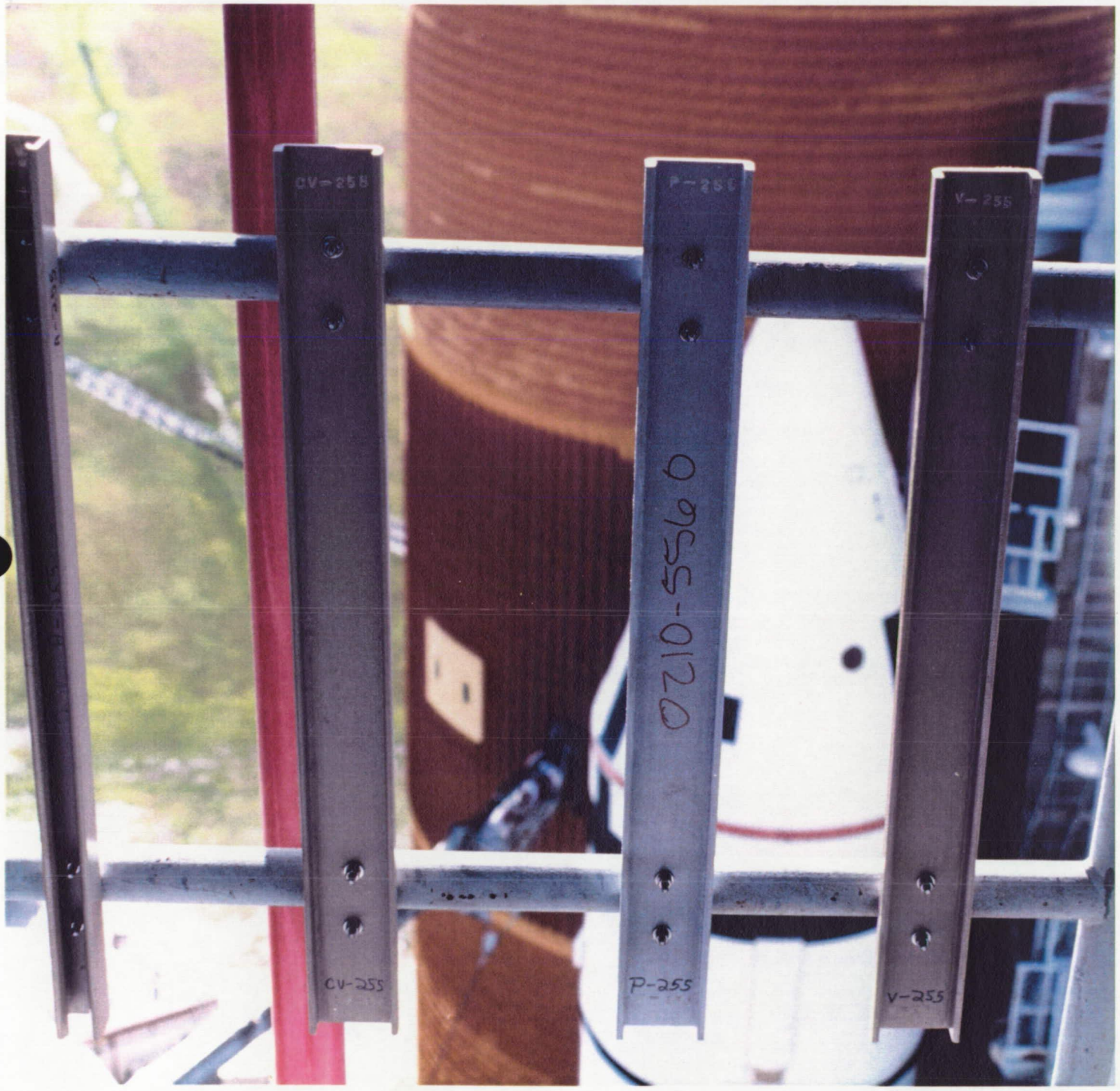
A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 19 June 1993 from 0910 - 1050 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (4th flight), ET-58 (LWT 51), and BI-059 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

There were no significant vehicle anomalies or debris issues. A Problem Report was taken to document damaged foam on the ET helium inject box. The PR was subsequently dispositioned to accept the condition for flight.

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

Two items were entered in S0007, Appendix K: 1) a loose cable tray clamp on the FSS 255 foot level; 2) loose bolts and one missing nut under the MLP zero level raised decks around the SRB exhaust holes.

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



Four each composite material samples were U-bolted to the hand rails on four levels of the FSS east side

3.0 SCRUB

The launch of STS-57 was scrubbed at T-5 minutes and holding due to RTLS and TAL site weather.

3.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 20 June 1993 from 0420 to 0550 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 violations. There were no conditions outside of the established data base. Ambient weather conditions at the time of the inspection were:

Temperature:	75.7 Degrees F
Relative Humidity:	71.1 Percent
Wind Speed:	6.29 Knots
Wind Direction:	117 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 1 and 2.

3.2 ORBITER

No Orbiter RCC panel or TPS anomalies were observed. All RCS thruster paper covers were intact, though the R4U and L2U covers had been wetted by vapors inside the thrusters. Less than usual ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. The base heat shield tiles were dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

3.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case temperatures between 78 and 80 degrees Fahrenheit (F). In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer ranged from 76 to 79 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures of 79-80 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 79 degrees F, which was within the required range of 44-86 degrees F.

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

TIME: 0400-0550
DATE: 6-20-93
VEH. STS- 57 Scrub

All temperatures are in degrees Fahrenheit.

Emissivity was set to 1.0

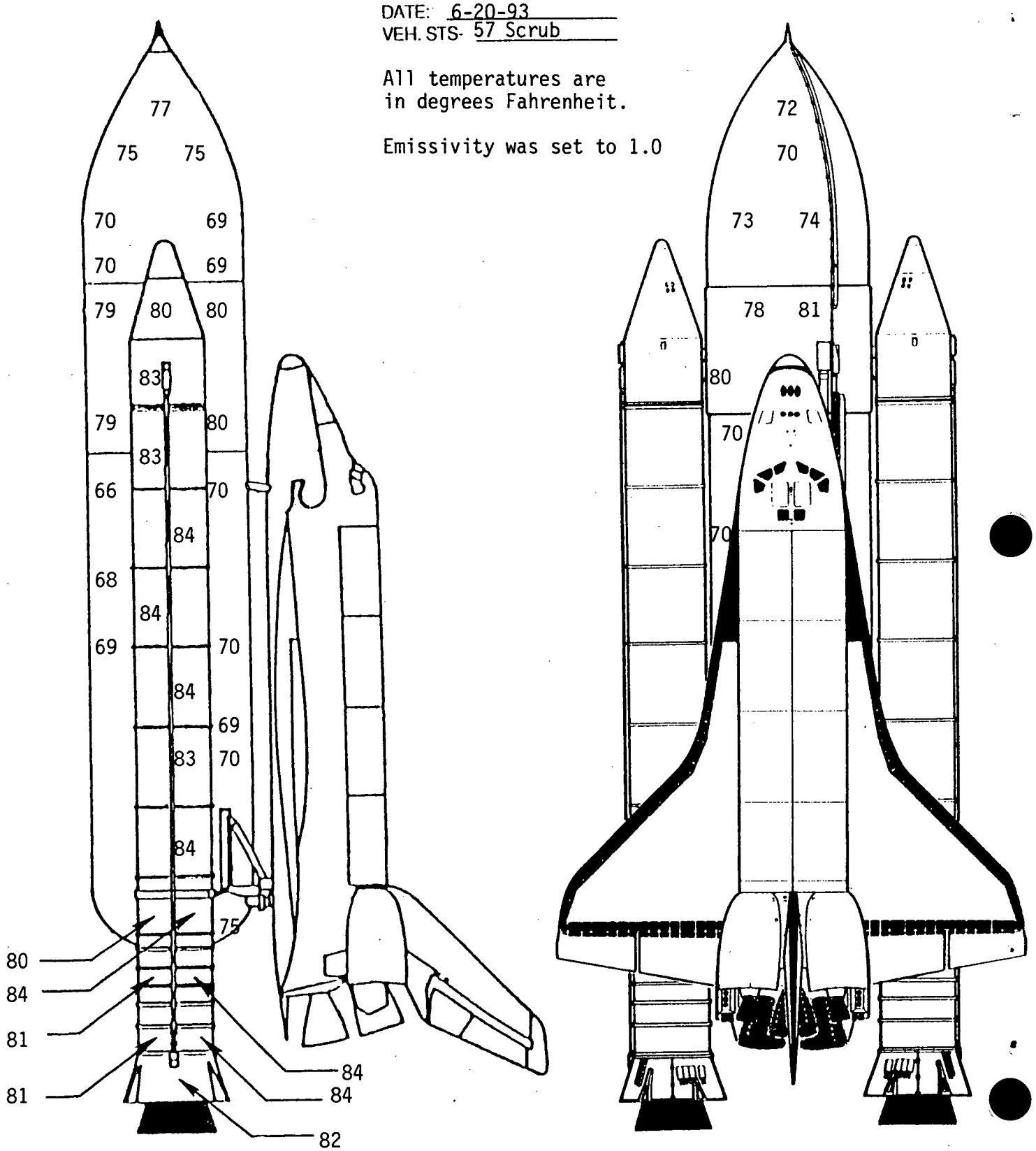
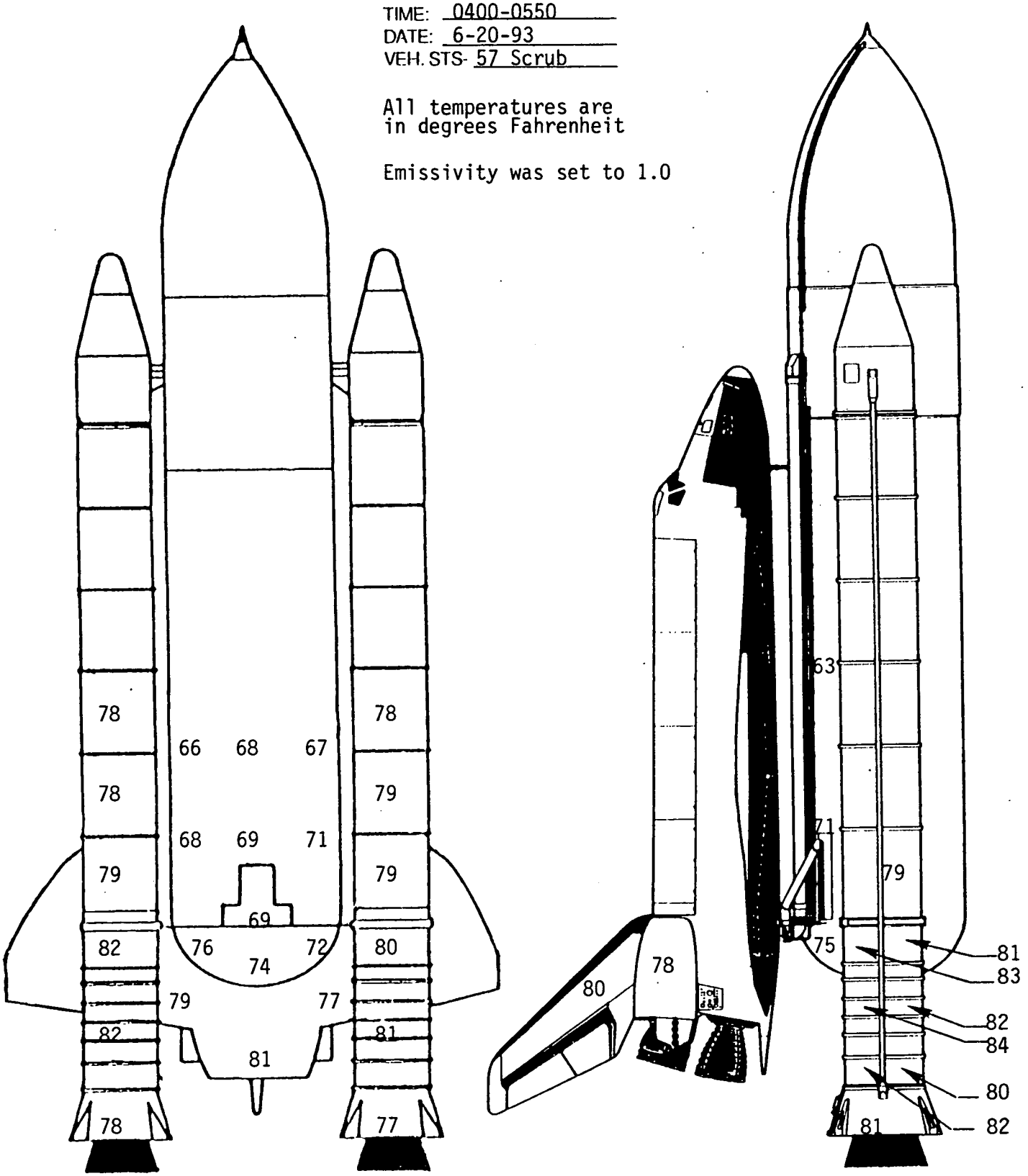


Figure 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0400-0550
DATE: 6-20-93
VEH. STS- 57 Scrub

All temperatures are in degrees Fahrenheit

Emissivity was set to 1.0



3.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0115 to 1030 hours and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

Light condensate, but no ice/frost accumulations, was observed by the Ice team on the LO2 tank ogive. There were no TPS anomalies. The tumble valve cover was intact. The portable STI measured surface temperatures that averaged 72 degrees F on the ogive and 69 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 71 degrees F on the ogive and 63 degrees F on the barrel; SURFICE predicted temperatures of 63 degrees F on the ogive and 58 degrees F on the barrel.

The intertank acreage TPS was dry. No frost spots appeared in the stringer valleys at the LH2 and LO2 tank-to-intertank flanges. Typical ice/frost accumulations and no unusual vapors were present on the ET umbilical carrier plate. The portable STI measured an average surface temperature of 79 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 69 degrees F on the upper LH2 tank and 67 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 65 degrees F on the upper and 63 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 48 degrees F on the upper LH2 tank and 61 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts. A 6-8 inch long by 3/8-inch wide crack was present in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface. This crack exhibited no offset and was not filled with ice or frost. The appearance of the crack was expected due to the elimination of the stress relief gap at the factory. A crack had also appeared in the +Y thrust strut-to-longeron interface.

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

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

STS- 57	TEST S0007 SCRUB - RTLS Weather														DATE: 20 June 1993					T-0 TIME: DATE:				NASA KSC Ice/Frost/Debris Team
ORBITER 105	ET 58	SRB BI-59	MLP 2	PAD B	LO2	CHILLDOWN TIME: 00:57	FAST FILL TIME: 01:43	SLOW FILL TIME: 01:32	REPLENISH TIME: 03:48		LH2	CHILLDOWN TIME: 00:57	FAST FILL TIME: 01:47	SLOW FILL TIME: 01:00	REPLENISH TIME: 03:40									
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0115	77.40	68.2	66.54	7	104	II	4.13	63.61	0.0013	-0.1658	II	4.13	58.91	0.0031	-0.1357	II	3.85	57.39	0.0034	-0.1211	II	8.54	63.07	0.0029	-0.2689
0130	77.40	68.6	62.30	6	97	II	3.54	60.35	0.0007	-0.1310	II	3.54	54.99	0.0023	-0.1021	II	3.30	53.31	0.0026	-0.0898	II	7.32	59.46	0.0018	-0.2047
0145	77.80	67.4	66.60	9	100	II	5.31	64.83	0.0010	-0.2059	II	5.31	60.96	0.0030	-0.1750	II	4.95	59.70	0.0034	-0.1580	II	10.98	64.52	0.0022	-0.3464
0200	77.20	67.8	66.18	7	103	II	4.13	63.29	0.0013	-0.1637	II	4.13	58.56	0.0031	-0.1336	II	3.85	57.06	0.0034	-0.1192	II	8.54	62.76	0.0028	-0.2654
0215	77.40	68.2	66.54	8	103	II	4.72	64.17	0.0012	-0.1851	II	4.72	59.92	0.0031	-0.1546	II	4.40	58.52	0.0035	-0.1389	II	9.76	63.77	0.0026	-0.3065
0230	77.20	68.6	66.51	8	103	II	4.72	64.06	0.0013	-0.1844	II	4.72	59.80	0.0031	-0.1539	II	4.40	58.41	0.0035	-0.1382	II	9.76	63.67	0.0027	-0.3053
0245	77.60	68.6	66.90	8	99	II	4.72	64.48	0.0013	-0.1875	II	4.72	60.24	0.0032	-0.1569	II	4.40	58.86	0.0035	-0.1410	II	9.76	64.09	0.0027	-0.3105
0300	77.60	67.8	66.57	8	100	II	4.72	64.27	0.0012	-0.1859	II	4.72	60.03	0.0031	-0.1553	II	4.40	58.64	0.0034	-0.1396	II	9.76	63.87	0.0026	-0.3077
0315	77.40	68.2	66.54	7	102	II	4.13	63.61	0.0013	-0.1658	II	4.13	58.91	0.0031	-0.1357	II	3.85	57.39	0.0034	-0.1211	II	8.54	63.07	0.0029	-0.2689
0330	77.40	68.6	66.71	6	106	II	3.54	63.02	0.0015	-0.1468	II	3.54	57.75	0.0032	-0.1171	II	3.30	56.09	0.0034	-0.1038	II	7.32	62.29	0.0032	-0.2322
0345	76.80	69.6	66.53	7	100	II	4.13	63.34	0.0015	-0.1640	II	4.13	58.61	0.0032	-0.1339	II	3.85	57.07	0.0035	-0.1194	II	8.54	62.83	0.0031	-0.2663
0400	78.00	69.8	67.78	8	90	II	4.72	65.21	0.0014	-0.1930	II	4.72	61.01	0.0033	-0.1622	II	4.40	59.64	0.0036	-0.1461	II	9.76	64.83	0.0029	-0.3201
0415	77.20	70.2	67.16	9	114	II	5.31	64.94	0.0013	-0.2069	II	5.31	61.08	0.0033	-0.1759	II	2.88	54.94	0.0035	-0.0908	II	12.51	65.24	0.0024	-0.3960
0430	76.00	70.2	65.98	6	114	II	3.54	61.92	0.0018	-0.1404	II	3.54	56.59	0.0032	-0.1109	II	1.92	49.04	0.0031	-0.0626	II	8.34	62.02	0.0032	-0.2529
0445	75.80	70.4	65.87	7	120	II	4.13	62.48	0.0015	-0.1584	II	4.13	57.70	0.0032	-0.1285	II	2.24	50.62	0.0032	-0.0827	II	9.73	62.69	0.0029	-0.2926
0500	75.20	71.0	66.51	6	120	II	3.54	61.26	0.0016	-0.1368	II	3.54	55.88	0.0032	-0.1071	II	1.92	48.25	0.0031	-0.0592	II	8.34	61.38	0.0032	-0.2462
0515	75.40	71.2	65.79	5	120	II	2.95	60.60	0.0017	-0.1191	II	2.95	54.52	0.0032	-0.0900	II	1.60	48.03	0.0030	-0.0604	II	6.95	60.53	0.0035	-0.2075
0530	74.60	72.2	65.39	5	110	II	2.95	59.96	0.0017	-0.1159	II	2.95	53.84	0.0032	-0.0869	II	2.75	51.86	0.0034	-0.0751	II	6.10	59.03	0.0036	-0.1769
0545	74.60	72.8	65.63	5	120	II	2.95	60.11	0.0018	-0.1166	II	2.95	53.99	0.0033	-0.0876	II	1.60	47.39	0.0031	-0.0578	II	6.95	60.08	0.0036	-0.2035
0600	75.00	73.4	66.25	6	107	II	3.54	61.63	0.0018	-0.1388	II	3.54	56.26	0.0034	-0.1093	II	3.30	54.54	0.0037	-0.0961	II	7.32	61.01	0.0037	-0.2201
0615	75.20	73.6	66.52	8	94	II	4.72	63.22	0.0017	-0.1784	II	4.72	58.92	0.0035	-0.1480	II	4.40	57.48	0.0038	-0.1324	II	9.76	62.92	0.0034	-0.2964
0630	76.00	72.6	66.93	8	97	II	4.72	63.82	0.0016	-0.1828	II	4.72	59.55	0.0035	-0.1522	II	4.40	58.13	0.0038	-0.1365	II	9.76	63.50	0.0033	-0.3035
0645	77.60	71.4	68.03	7	96	II	4.13	64.65	0.0016	-0.1729	II	4.13	59.99	0.0034	-0.1425	II	3.85	58.47	0.0038	-0.1275	II	8.54	64.16	0.0034	-0.2814
0700	78.00	69.6	67.70	8	92	II	4.72	65.16	0.0014	-0.1926	II	4.72	60.96	0.0033	-0.1618	II	4.40	59.59	0.0036	-0.1457	II	9.76	64.77	0.0029	-0.3194
0715	78.20	69.2	67.74	9	86	II	5.31	65.72	0.0012	-0.2133	II	5.31	61.90	0.0032	-0.1821	II	4.95	60.63	0.0036	-0.1647	II	10.98	65.42	0.0026	-0.3594
0730	78.40	68.2	67.52	7	84	II	4.13	64.66	0.0014	-0.1729	II	4.13	60.02	0.0032	-0.1426	II	3.85	58.52	0.0035	-0.1277	II	8.54	64.12	0.0029	-0.2807
0745	78.20	68.8	67.57	9	86	II	5.31	65.61	0.0012	-0.2124	II	5.31	61.78	0.0032	-0.1813	II	4.95	60.52	0.0035	-0.1639	II	10.98	65.31	0.0025	-0.3578
0800	78.40	68.4	67.61	10	95	II	5.90	66.09	0.0010	-0.2329	II	5.90	62.59	0.0030	-0.2014	II	5.50	61.41	0.0035	-0.1828	II	12.20	65.86	0.0022	-0.3976
0815	78.40	68.6	67.69	11	94	II	6.49	66.47	0.0009	-0.2530	II	6.49	63.22	0.0030	-0.2212	II	6.05	62.13	0.0034	-0.2013	II	13.42	66.29	0.0019	-0.4370
0830	78.60	68.2	67.72	7	98	II	4.13	64.87	0.0014	-0.1743	II	4.13	60.24	0.0032	-0.1439	II	3.85	58.74	0.0035	-0.1290	II	8.54	64.33	0.0030	-0.2831
0845	78.60	68.2	67.72	8	87	II	4.72	65.42	0.0012	-0.1945	II	4.72	61.23	0.0032	-0.1637	II	4.40	59.86	0.0035	-0.1475	II	9.76	65.01	0.0027	-0.3222
0900	79.20	65.6	67.21	10	104	II	5.90	66.15	0.0007	-0.2333	II	5.90	62.64	0.0028	-0.2018	II	5.50	61.50	0.0032	-0.1833	II	12.20	65.88	0.0016	-0.3976
0915	79.20	65.0	66.96	10	112	II	5.90	65.99	0.0006	-0.2318	II	5.90	62.47	0.0027	-0.2004	II	5.50	61.33	0.0031	-0.1819	II	12.20	65.70	0.0015	-0.3948
0930	79.60	64.2	67.00	9	107	II	6.31	65.80	0.0007	-0.2137	II	5.31	62.00	0.0027	-0.1827	II	4.95	60.76	0.0031	-0.1654	II	10.98	65.43	0.0017	-0.359
0945	79.60	63.0	66.47	8	119	II	4.72	65.04	0.0008	-0.1914	II	4.72	60.84	0.0027	-0.1608	II	2.56	54.59	0.0030	-0.0836	II	11.12	65.14	0.0015	-0.3582
1000	80.00	63.6	67.12	9	121	II	5.31	66.04	0.0006	-0.2157	II	5.31	62.25	0.0026	-0.1846	II	2.88	56.39	0.0031	-0.0974	II	12.51	66.20	0.0012	-0.4106
1015	79.80	62.0	66.21	9	103	II	5.31	65.39	0.0005	-0.2102	II	5.31	61.57	0.0025	-0.1793	II	4.95	60.33	0.0029	-0.1623	II	10.98	64.99	0.0013	-0.3524
1030	80.20	61.8	66.51	10	109	II	5.90	66.10	0.0003	-0.2326	II	5.90	62.60	0.0023	-0.2012	II	5.50	61.46	0.0028	-0.1829	II	12.20	65.77	0.0009	-0.3954
AVG.	77.53	68.28	66.67	7.76	E		4.61	64.04				4.58	59.59				3.94	57.07				9.72	63.71		

Period of Ice Team Inspection

Figure 3. "SURFICE" Computer Predictions

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were covered with condensate. Less than usual amounts of ice/frost had accumulated on the top, aft, and outboard sides of the LH2 ET/ORB umbilical purge barrier. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the forward outboard and aft pyrotechnic canister closeout bondlines indicating thermal shorts. Ice/frost had formed on the 17-inch flapper valve actuator access port foam plug closeout forward corner as a result of a small cold purge gas leak. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

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

The summary of Ice/Frost Team observations/anomalies, which were acceptable for launch per the NSTS-08383 criteria, consisted of three OTV recorded items:

Anomaly 001 documented a 6-8 inch long by 3/8-inch wide crack in the -Y vertical strut cable tray forward surface near the longeron closeout interface. The crack exhibited no offset and was not filled with ice or frost.

Anomaly 002 documented a crack in the thrust strut-to-longeron interface (+Y side).

Anomaly 003 (documentation only) recorded ice/frost formations in the LH2 feedline bellows, recirculation line bellows and burst discs, the ET/ORB LH2 and LO2 umbilicals, LO2 feedline bellows and support brackets.

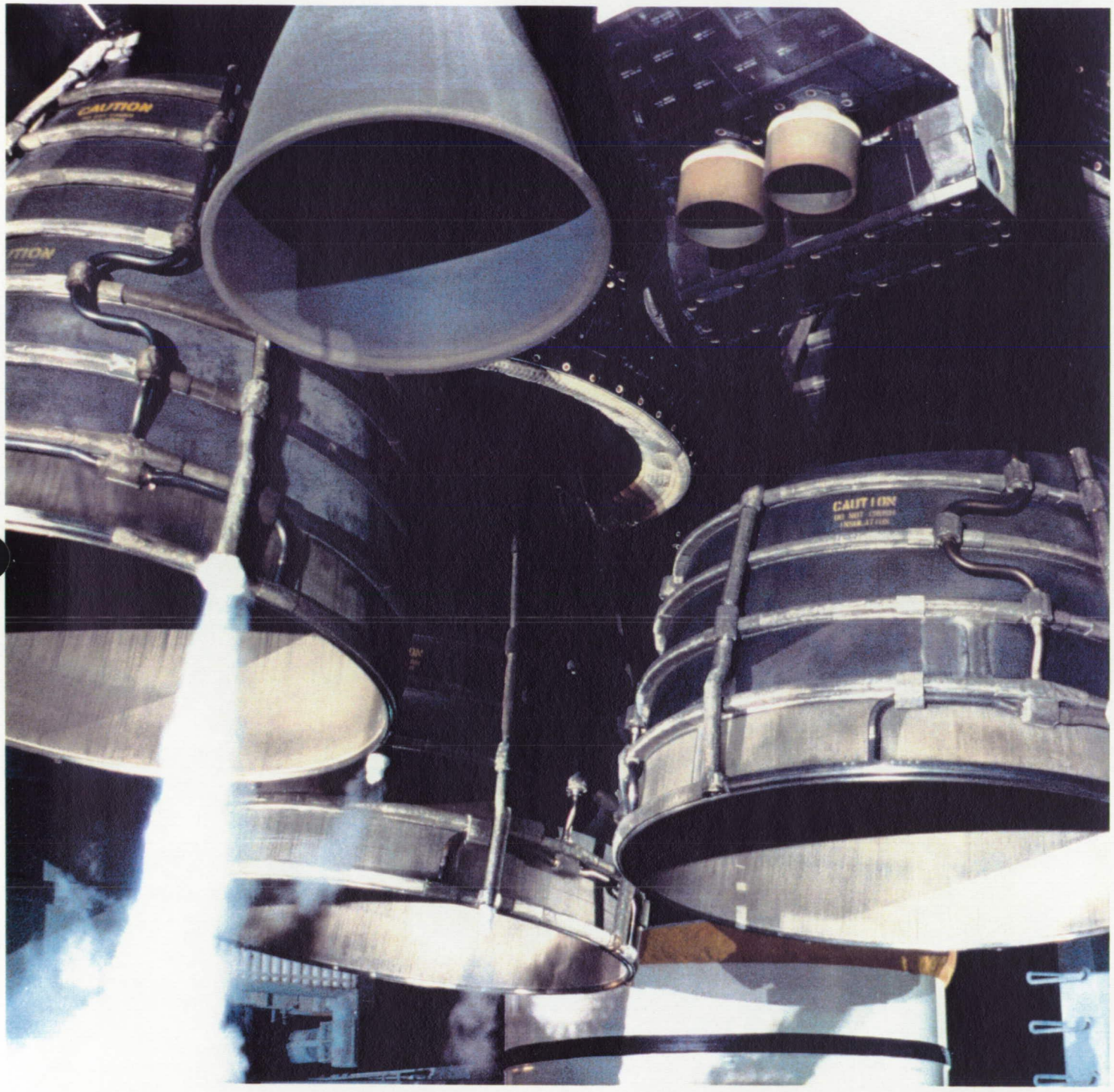
3.5 FACILITY

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

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

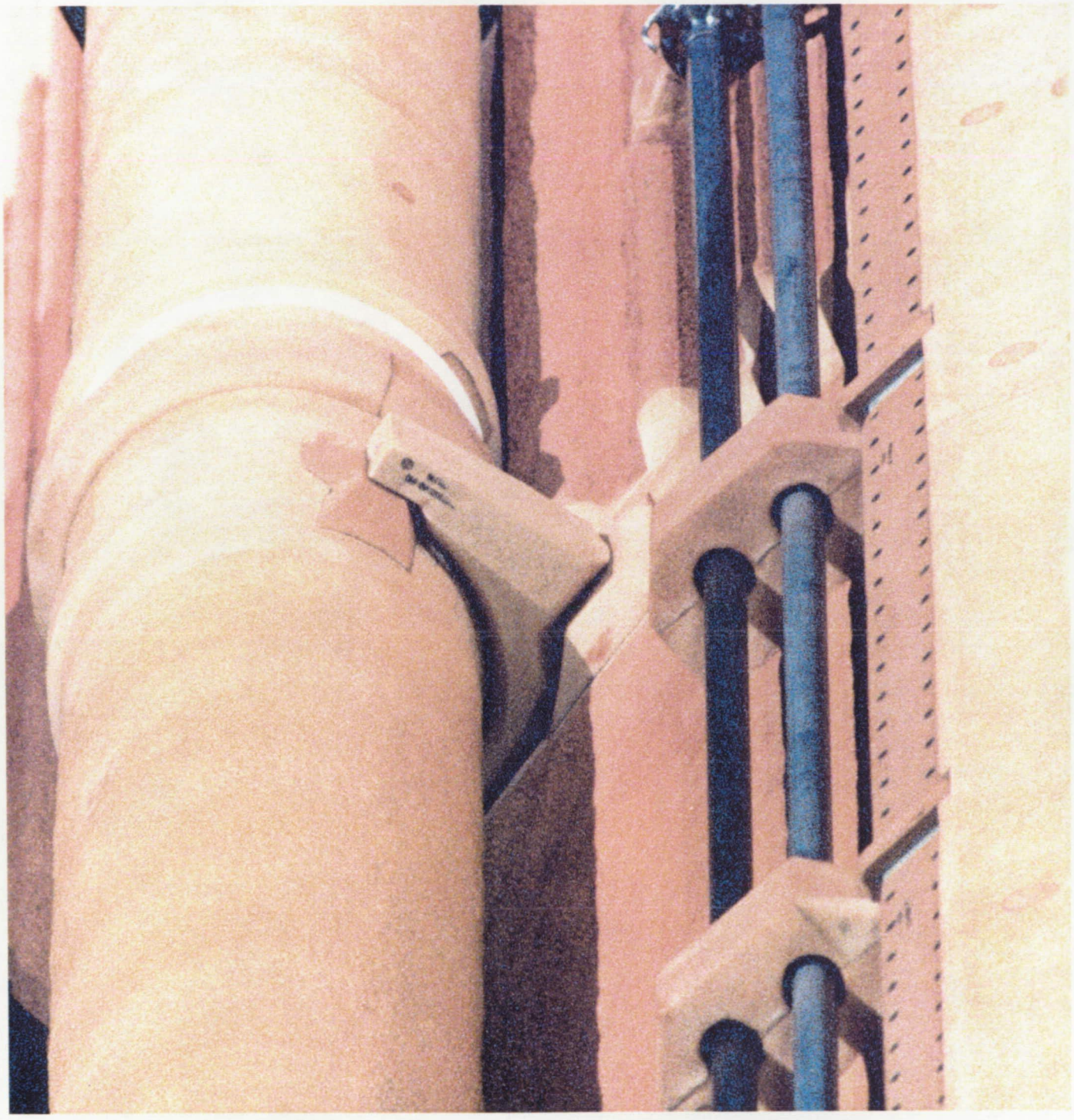
There was no apparent hydrogen leakage anywhere on the GH2 vent line or GUCP. Some ice and frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. No icicles were present on the GOX vent ducts at the time of launch.

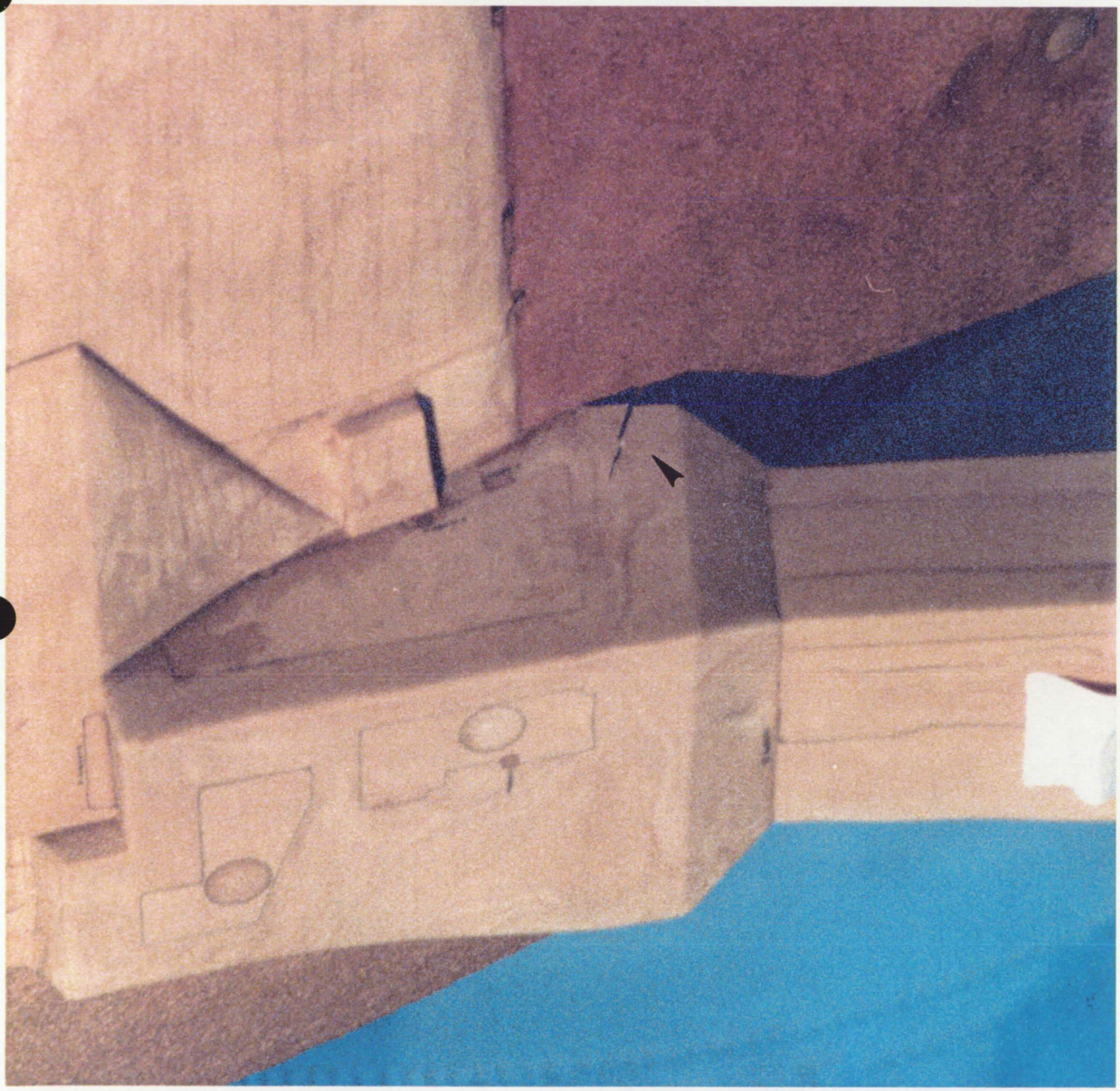


Overall view of the Shuttle main engines

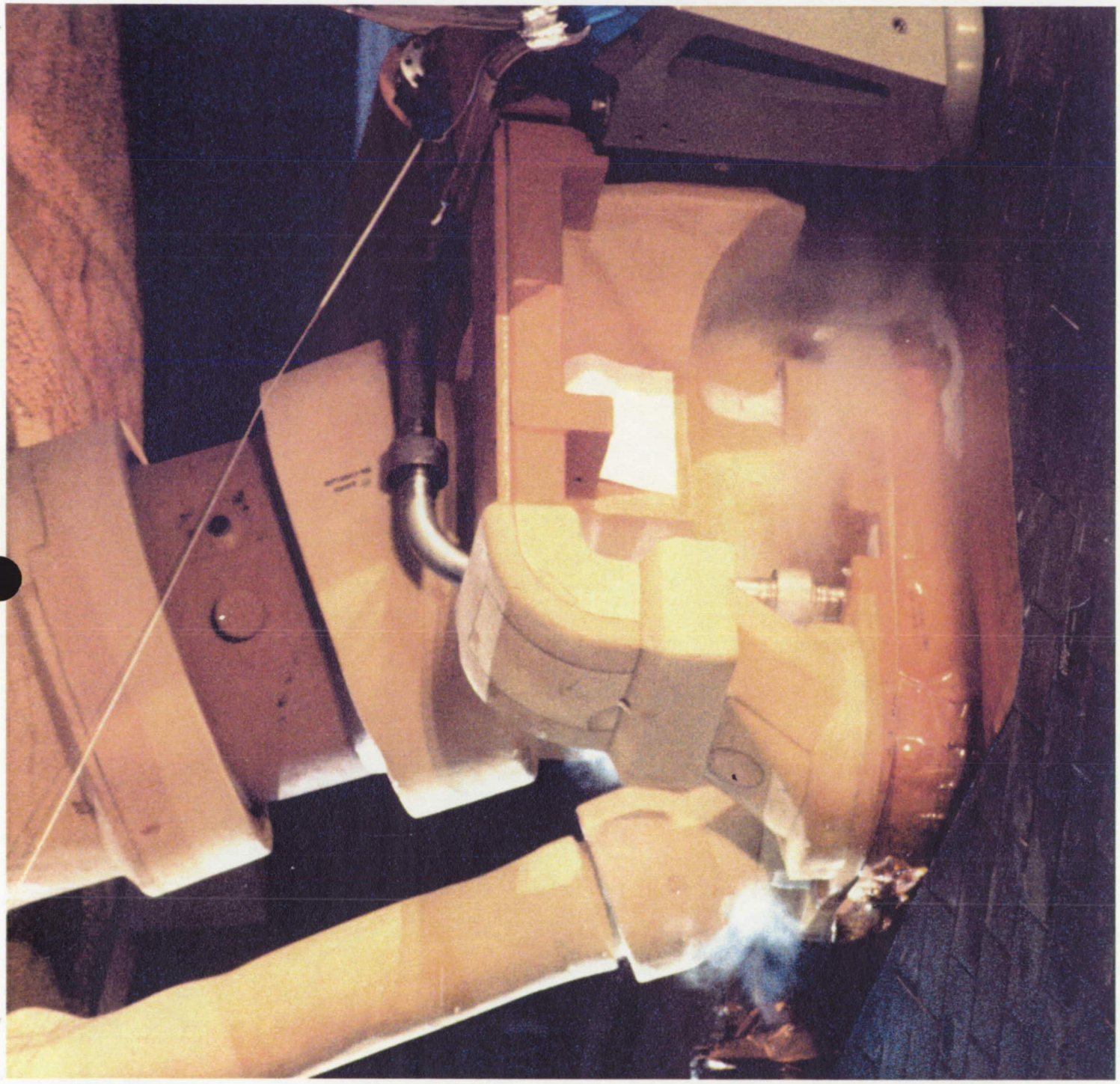
Condensate, but no ice or frost, was present on the LH2 tank acreage. There were no acreage TPS anomalies.



Ice/frost accumulations in the LO2 feedline bellows
and support brackets was typical



An 8-inch long by 3/8-inch wide crack occurred in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface. The crack exhibited no offset and was not filled with ice or frost. The presence of the crack was acceptable for flight per the NSTS-08303 criteria.



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

3.6 POST DRAIN VEHICLE INSPECTION

The launch of STS-57 was scrubbed at T-5 minutes and holding due to RTLS and TAL site weather. A post drain inspection of the vehicle was performed at Pad-39B on 20 June 1993 from 1730 to 1845 hours.

There were no anomalies on the Orbiter, Solid Rocker Boosters, or launch pad/facility.

There was no visible damage on the External Tank nosecone or fairing. Three small areas of topcoat were missing from the -Y footprint area. The +Y footprint area was not accessible for inspection. The tumble valve cover was intact.

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

Ice in the LO2 feedline support brackets and bellows had melted. No loose foam or TPS damage was visible.

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

The 8 x 3/8-inch crack in the -Y ET/SRB vertical strut cable tray forward surface TPS (reported during the Ice Inspection) was still visible. A 5 x 1/8-inch crack was present in the +Y ET/SRB vertical strut cable tray aft surface TPS. The crack had an 1/8-inch offset, approximately, due to structural deflection. Further inspection revealed the crack continued into the vertical strut/LH2 tank crotch area and progressed 6 inches upward within the BX-250 closeout. No ice was visible in the crack.

Ice on the ET/SRB fittings, the LO2 and LH2 ET/ORB umbilical purge vents, the LH2 recirculation line bellows and burst disks, the LH2 feedline bellows, and the LH2 umbilical 17-inch flapper valve torque tool access port closeout plug had not yet completely melted. More ice than usual remained on the LH2 ET/ORB umbilical aft pyrotechnic canister closeout bondlines.

Ice/frost spots that had formed on the aft dome -Z manhole cover closeouts during detanking had melted and no TPS damage was visible.

No significant vehicle damage was observed during the external post drain inspection. Two PR's were generated as a result of this inspection: 1) missing topcoat in the footprint area; 2) 5-inch crack in the +Y vertical strut cable tray TPS.

Post drain inspection revealed ice on the pyro canister purge vents, plate gap purge vents, LH2 recirculation line bellows, and LH2 feedline bellows - an expected condition. There were no TPS anomalies.

4.0 LAUNCH

STS-57 was launched at 13:07:21.989 GMT (9:07 a.m. local) on 21 June 1993.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 21 June 1993 from 0510 to 0615 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. Ambient weather conditions at the time of the inspection were:

Temperature:	76.3 Degrees F
Relative Humidity:	76.7 Percent
Wind Speed:	4.2 Knots
Wind Direction:	147 Degrees

Cryogenic loading of the External Tank began almost two hours late due to the replacement of a malfunctioning nitrogen regulator in the MLP. An inspection of the vehicle by the Ice Team was necessary since the ET had already experienced one cryoloading. However, the regulator problem and a short launch window dictated the need for an abbreviated inspection of the vehicle. Expedited visual assessment with minimal photography/ infrared temperature measurements was performed.

4.2 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers, including the two wet covers on the R4U and L2U nozzles, and water spray boiler plugs were intact. Typical ice/frost accumulations were present at the SSME #1 heat shield-to-nozzle interface and drain line. Condensate was present on the SSME engine mounted heat shields, but the base heat shield tiles were dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

4.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. 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.

4.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0215 to 0900 hours and the results tabulated in Figure 4. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Ice Team observed no condensate or ice/frost accumulations on the LO2 tank ogive. Some light condensate was present on the LO2 tank barrel section. Due to an abbreviated inspection, an infrared scan of the vehicle was performed, but no spot or point measurements were taken. There were no TPS anomalies. The tumble valve cover was intact.

The intertank acreage TPS was dry. One ice/frost spot appeared on a stringer at the LH2 tank-to-intertank flange closeout. Typical ice/frost accumulations, but no unusual vapors, were present on the ET umbilical carrier plate.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. There were no anomalies on the bipod jack pad closeouts. A two inch diameter ice/frost accumulation, which had first appeared during the scrub drain, had formed on the -Y bipod spindle housing-to-ET interface bondline.

A 6-8 inch long by 3/8-inch wide crack was again visible in the -Y vertical strut cable tray forward surface TPS. A 5-inch by 1/4-inch wide crack occurred on the +Y vertical strut aft side TPS-to-ET interface bondline. The cracks exhibited no offset and were not filled with ice or frost. A crack was observed in the -Y thrust strut-to-longeron interface. These conditions were acceptable for flight per the NSTS-08303 criteria.

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

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. Less than usual accumulations of ice/frost were present on the acreage areas of the umbilical. Formation of ice/frost fingers on the separation bolt pyro canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. An ice/frost formation appeared at the LH2 recirculation line-to-LH2 tank aft dome interface. The LH2 feedline bellows were wet with condensate and some frost was beginning to form.

STS- 57	TEST S0007 LAUNCH															DATE: 21 June 1993					T-0 TIME: 09:07:21.989 DATE: 6/21/93				NASA KSC Ice/Frost/Debris Team
ORBITER 105	ET 58	SRB BI-059	MLP 2	PAD B	LO2 CHILLDOWN TIME: 02:19 SLOW FILL TIME: 02:46						FAST FILL TIME: 02:58 REPLENISH TIME: 05:02					LH2 CHILLDOWN TIME: 02:08 SLOW FILL TIME: 02:16					FAST FILL TIME: 03:01 REPLENISH TIME: 04:47				
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0215	77.40	73.8	68.76	7	122	II	4.13	65.04	0.0018	-0.1757	II	4.13	60.40	0.0036	-0.1452	II	2.24	53.43	0.0036	-0.0737	II	9.73	65.27	0.0035	-0.3253
0230	77.20	74.2	68.72	7	136	II	4.13	64.93	0.0018	-0.1749	II	4.13	60.28	0.0037	-0.1444	II	2.24	53.28	0.0036	-0.0731	II	9.73	65.16	0.0036	-0.3240
0245	77.40	74.6	69.07	8	134	II	4.72	65.81	0.0018	-0.1978	II	4.72	61.64	0.0037	-0.1667	II	2.56	55.09	0.0037	-0.0859	II	11.12	66.11	0.0034	-0.3736
0300	77.40	74.0	68.84	4	130	II	2.36	62.29	0.0019	-0.1128	II	2.36	55.43	0.0034	-0.0837	II	1.28	51.03	0.0033	-0.0739	II	5.56	61.92	0.0040	-0.1884
0315	77.40	74.4	68.99	7	126	II	4.13	65.19	0.0019	-0.1768	II	4.13	60.56	0.0037	-0.1462	II	2.24	53.58	0.0036	-0.0743	II	9.73	65.43	0.0036	-0.3274
0330	77.20	74.2	68.72	7	133	II	4.13	64.93	0.0018	-0.1749	II	4.13	60.28	0.0037	-0.1444	II	2.24	53.28	0.0036	-0.0731	II	9.73	65.16	0.0036	-0.3240
0345	77.20	74.6	68.87	6	137	II	3.54	64.32	0.0019	-0.1549	II	3.54	59.11	0.0037	-0.1248	II	1.92	51.63	0.0034	-0.0734	II	8.34	64.46	0.0038	-0.2800
0400	77.40	74.8	69.14	5	145	II	2.95	63.68	0.0020	-0.1353	II	2.95	57.77	0.0036	-0.1056	II	1.60	51.20	0.0034	-0.0747	II	6.95	63.64	0.0040	-0.2368
0415	76.20	75.2	68.11	6	126	II	3.54	63.38	0.0019	-0.1492	II	3.54	58.11	0.0036	-0.1193	II	1.92	50.53	0.0034	-0.0685	II	8.34	63.55	0.0039	-0.2699
0430	76.60	75.4	68.58	7	123	II	4.13	64.58	0.0019	-0.1726	II	4.13	59.91	0.0037	-0.1421	II	2.24	52.85	0.0036	-0.0714	II	9.73	64.85	0.0037	-0.3200
0445	76.80	76.0	69.00	6	130	II	3.54	64.23	0.0020	-0.1544	II	3.54	59.01	0.0037	-0.1243	II	1.92	51.48	0.0035	-0.0726	II	8.34	64.40	0.0040	-0.2794
0500	77.00	75.2	68.90	6	137	II	3.54	64.25	0.0020	-0.1545	II	3.54	59.04	0.0037	-0.1244	II	1.92	51.53	0.0034	-0.0729	II	8.34	64.40	0.0039	-0.2794
0515	77.00	75.4	68.98	4	157	II	2.36	62.17	0.0020	-0.1123	II	2.36	55.30	0.0034	-0.0832	II	1.28	50.84	0.0034	-0.0731	II	5.56	61.84	0.0042	-0.1878
0530	76.80	76.4	69.15	3	145	II	1.77	60.47	0.0019	-0.1032	II	1.77	52.28	0.0032	-0.0786	II	0.96	50.80	0.0034	-0.0730	II	4.17	59.57	0.0042	-0.1410
0545	76.00	77.6	68.80	5	145	II	2.95	62.80	0.0021	-0.1307	II	2.95	56.82	0.0037	-0.1011	II	1.60	50.07	0.0034	-0.0697	II	6.95	62.84	0.0043	-0.2293
0600	75.00	77.0	68.68	4	147	II	2.36	61.42	0.0020	-0.1089	II	2.36	54.49	0.0035	-0.0799	II	1.28	49.94	0.0034	-0.0691	II	5.56	61.14	0.0043	-0.1824
0615	75.60	77.2	68.26	5	140	II	2.95	62.26	0.0021	-0.1279	II	2.95	56.25	0.0036	-0.0984	II	1.60	49.50	0.0034	-0.0671	II	6.95	62.30	0.0042	-0.2242
0630	75.60	77.8	68.48	5	141	II	2.95	62.41	0.0021	-0.1286	II	2.95	56.40	0.0037	-0.0991	II	1.60	49.62	0.0034	-0.0677	II	6.95	62.46	0.0043	-0.2257
0645	77.20	77.8	70.06	3	135	II	1.77	61.26	0.0020	-0.1069	II	1.77	53.12	0.0033	-0.0823	II	0.96	51.57	0.0035	-0.0786	II	4.17	60.39	0.0044	-0.1462
0700	77.00	78.2	70.00	2	147	II	1.18	59.76	0.0019	-0.1062	II	1.18	52.82	0.0033	-0.0815	II	0.64	51.41	0.0035	-0.0759	II	2.78	56.39	0.0041	-0.0958
0715	77.40	79.4	70.83	3	135	II	1.77	61.86	0.0021	-0.1097	II	1.77	53.76	0.0034	-0.0850	II	0.96	52.14	0.0036	-0.0793	II	4.17	61.03	0.0045	-0.1504
0730	77.00	77.8	69.86	1	181	II	0.59	59.68	0.0019	-0.1058	II	0.59	52.74	0.0033	-0.0811	II	0.42	51.33	0.0035	-0.0755	II	0.38	51.33	0.0035	-0.0755
0745	77.80	74.6	69.46	1	203	II	0.59	59.96	0.0018	-0.1069	II	0.59	53.04	0.0031	-0.0823	II	0.32	51.64	0.0034	-0.0767	II	1.36	51.64	0.0034	-0.0767
0800	80.00	71.6	70.47	3	130	II	1.77	62.99	0.0018	-0.1162	II	1.77	55.03	0.0031	-0.0916	II	0.96	53.66	0.0034	-0.0860	II	4.17	61.95	0.0039	-0.1560
0815	80.00	71.6	70.47	3	130	II	1.77	62.99	0.0018	-0.1162	II	1.77	55.03	0.0031	-0.0916	II	0.96	53.66	0.0034	-0.0860	II	4.17	61.95	0.0039	-0.1560
0830	81.00	66.8	69.49	4	141	II	2.36	64.46	0.0015	-0.1228	II	2.36	57.79	0.0031	-0.0936	II	1.28	53.76	0.0031	-0.0862	II	5.56	63.87	0.0034	-0.2038
0845	81.20	65.0	68.91	4	85	II	2.36	64.19	0.0014	-0.1215	II	2.36	57.52	0.0029	-0.0924	II	2.20	55.49	0.0032	-0.0852	II	4.88	62.63	0.0033	-0.1774
0900	80.80	64.0	68.08	7	78	II	4.13	66.03	0.0010	-0.1822	II	4.13	61.48	0.0029	-0.1516	II	3.85	60.05	0.0032	-0.1365	II	8.54	65.40	0.0024	-0.2951
T-0	81.40	64.0	68.67	5	92	II	2.95	65.22	0.0013	-0.1434	II	2.95	59.48	0.0029	-0.1137	II	2.75	57.69	0.0032	-0.1009	II	6.10	64.09	0.0030	-0.2191
AVG.	77.69	74.09	69.11	4.76	SSE		2.81	63.19				2.81	57.07				1.65	52.49				6.48	62.25		

Period of Ice Team Inspection

Figure 4. "SURFICE" Computer Predictions

Less than usual amounts of ice/frost had accumulated on the top, aft, and outboard sides of the LH2 ET/ORB umbilical purge barrier. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Light ice/frost was present on both the aft and forward outboard pyrotechnic canister closeout bondlines indicating thermal shorts. Cold purge gas was leaking from the 17-inch flapper valve actuator access port foam plug closeout forward corner. Ice/frost had formed as a result. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The ET/ORB hydrogen detection sensor tygon tubing had not been installed during the scrub turnaround.

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

Anomaly 001 documented a frost spot in a stringer root at the LH2 tank-to-intertank splice (-Y-Z quadrant).

Anomaly 002 documented a 2-inch diameter ice/frost spot with vapors on the outboard side of the -Y bipod spindle housing-to-ET interface bondline.

Anomaly 003 documented cracks in both +Y and -Y thrust strut-to-longeron interfaces.

Anomaly 004 documented a 6-8 inch long by 3/8-inch wide crack in the -Y vertical strut cable tray forward surface TPS near the longeron closeout. A 5-inch long by 1/4-inch wide crack occurred in the +Y vertical strut aft surface TPS along the ET interface. The cracks exhibited no offset and were not filled with ice or frost.

Anomaly 005 documented ice/frost formations on the aft hard point attach pad bondlines.

Anomaly 006 (documentation only) recorded ice/frost formations on the ET/ORB umbilical pyro canister purge vents and LH2 upper/outboard sections of the purge barrier (baggie), LO2 feedline support brackets and bellows, LH2 feedline bellows, recirculation line bellows and burst disks.

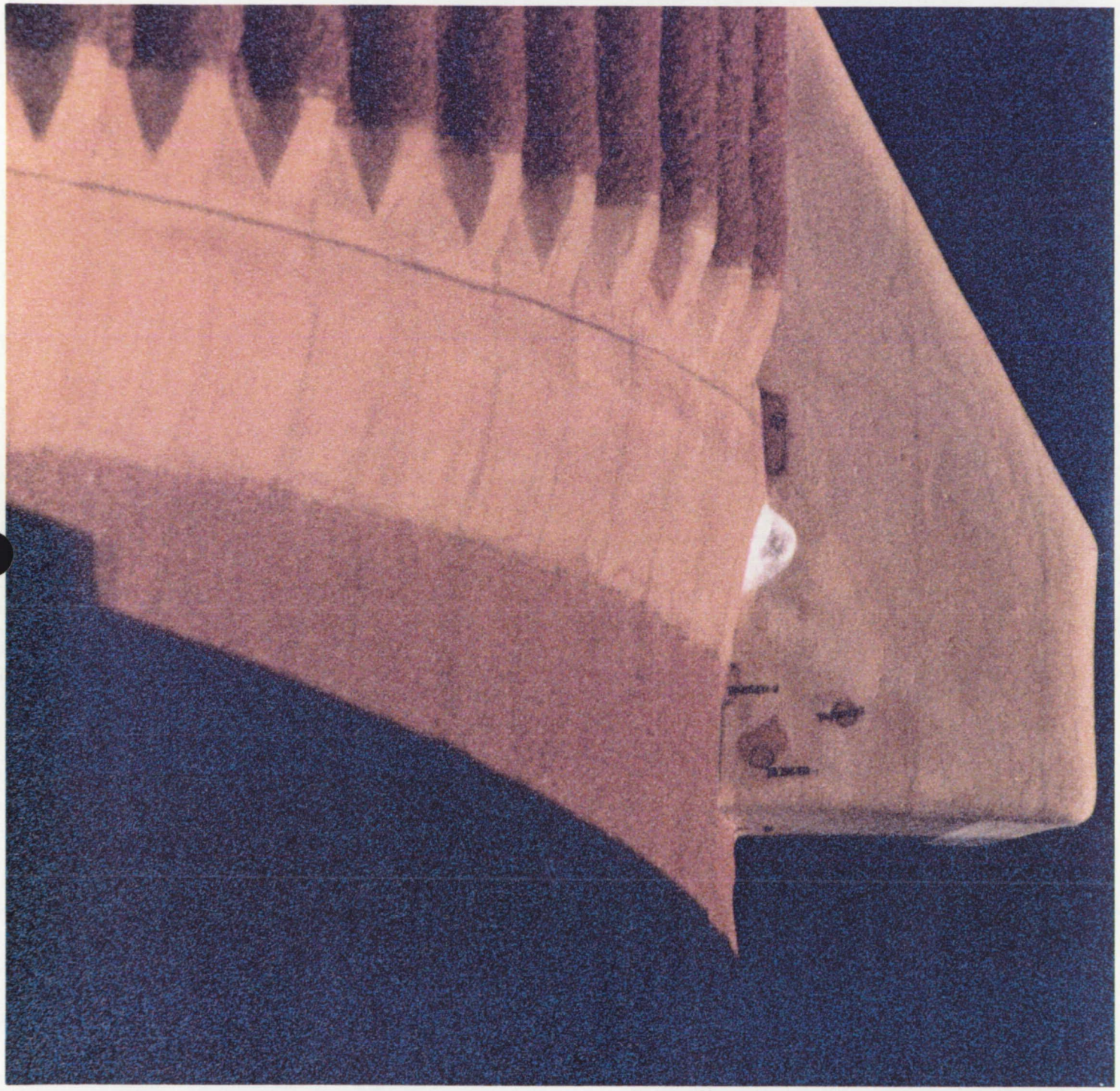
4.5 FACILITY

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

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

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

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



A 2-inch diameter ice/frost accumulation, which first appeared during drain, had formed on the -Y bipod spindle housing-to-ET interface bondline.

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP and FSS/RSS was conducted on 21 June 1993 from Launch + 2 to 3-1/2 hours.

A frangible nut web, 2-1/4" x 5/16", was found on the stud in holddown post (HDP) #2. A Q-felt plug from the Orbiter base heat shield was found on the southwest pad apron.

Three metal facility items (1-3/8" x 1/4" bolt, 5/8" x 1/4" bolt, 7/8" diameter washer) lay on the MLP deck near HDP #8 between the sound suppression water pipe and SRB exhaust hole.

South SRB HDP erosion was typical. All south HDP EPON shoe shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. Plume erosion of the covers was typical with the exception of the HDP #4 cover, which had several burn-through holes. The SRB aft skirt purge lines were in place, but slightly damaged. The SRB T-0 umbilicals exhibited minor damage.

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

Typical damage to the facility included:

1. An aluminum ring, 3 inches in diameter, lay on the pad apron under the RSS. A 2-1/4" x 1/4" diameter flexible white tube with stainless steel clamp and UV detector cap were found in the SSME flame trench.

2. A piece of porcelain, two cable tray clamps, a 16" long by 1/2" strip of aluminum, a FOD sign, a loose bolt, and a grating clamp were found on various levels of the FSS/RSS.

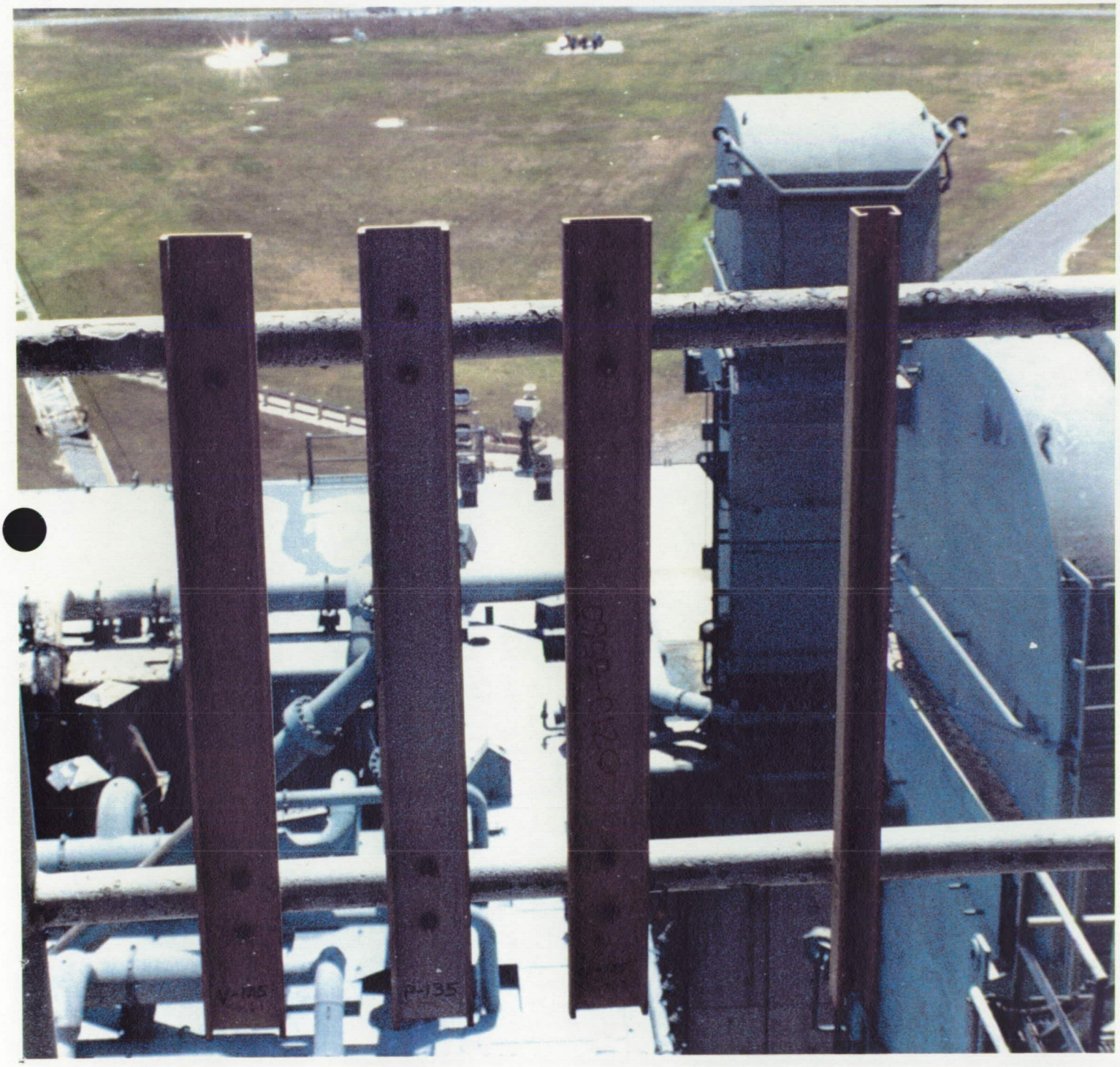
All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

All composite material samples on the FSS side 1, levels 135, 175, 215, and 255 hand rails, were intact and undamaged.

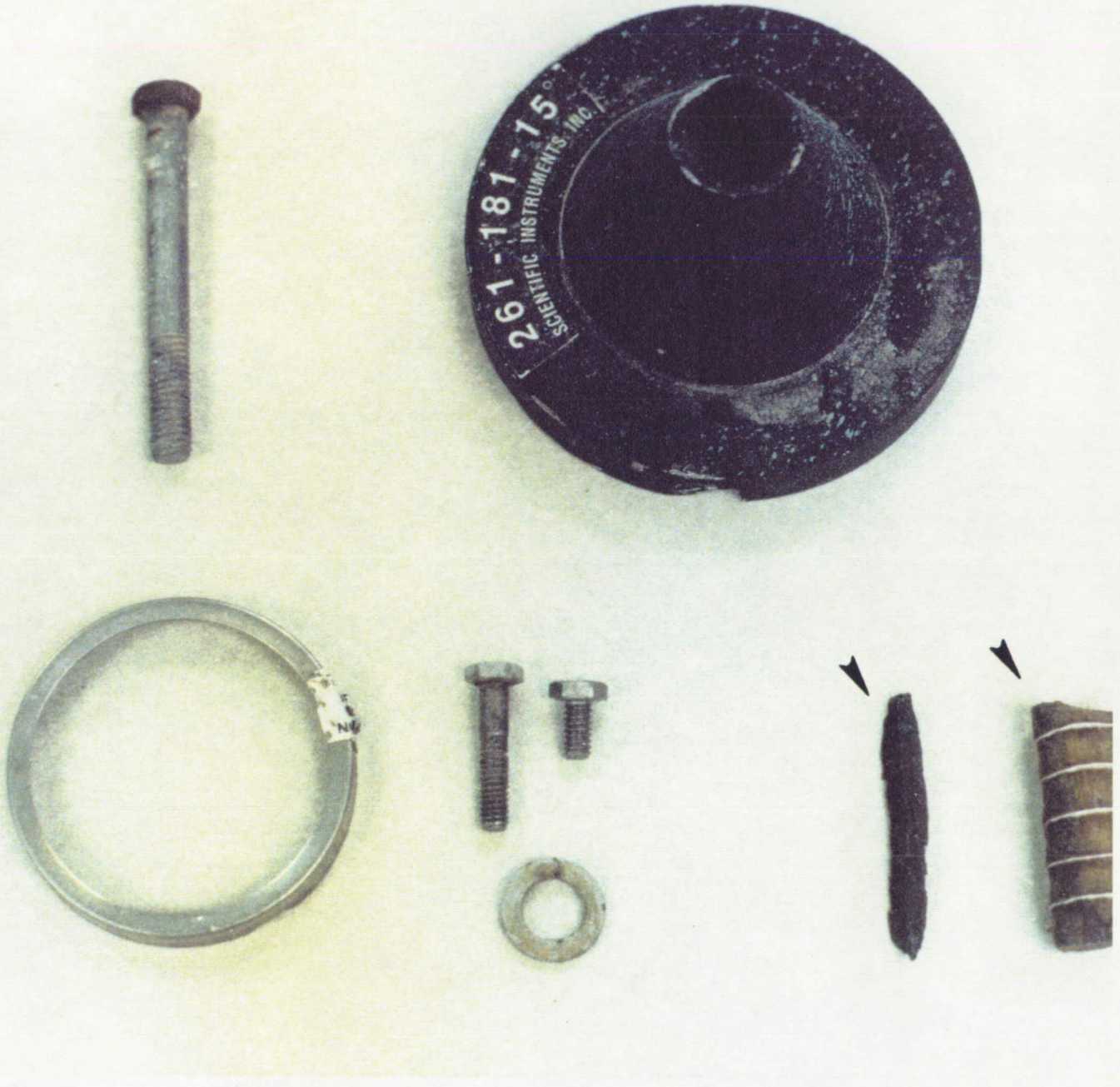
A walkdown of the pad acreage and beach was completed on 22 June 1993. No flight hardware or TPS material was found.

Post launch pad inspection anomalies are listed in Section 10.

SRB plume erosion of the north HDP blast covers was typical with the exception of the HDP #4 cover, which had several burn-through holes.



All composite material samples attached to the
FSS east side handrails were intact and undamaged



A frangible nut web, 2-1/4" by 5/16", was found on the stud in holddown post #2. A Q-felt plug from the Orbiter base heat shield was found on the southwest pad apron.

6.0 FILM REVIEW AND PROBLEM REPORTS

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. Two IFA candidates were proposed as a result of the film review.

6.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 104 films and videos, which included forty-one 16mm films, twenty 35mm films, four 70mm films, and thirty-nine videos, were reviewed starting on launch day.

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

Free burning hydrogen drifted under the body flap prior to SSME ignition. Frost covered the SSME nozzles. SSME ignition, Mach diamond formation, and gimbal profile appeared normal (C/S-2 STI, OTV 151, 163, 170, 171, E-6, 19, 20). Flashes occurred in the SSME plumes prior to and after T-0 (E-2, 3).

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

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

Several pieces of ice from the GUCP area fell aft along the -Z side of the tank after SSME ignition (E-4).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150, 163). GUCP disconnect and retraction from the External Tank was normal (E-33, 34). The GH2 vent arm retracted and latched with no rebound (OTV 160). Some slack in the static retract lanyard caused the cable to contact the GUCP leg during latchback (E-41, 42, 48, 50). Excessive slack on the cable attached to the GUCP J2 electrical connector caused the cable to momentarily catch on a intertank access platform hand rail during retraction (E-42, 48).

No stud hang-ups occurred on any of the holddown posts. Two frangible nut pieces fell from the HDP #2 DCS/stud hole after liftoff (E-8). A loose SRB sound suppression water trough cloth parts tag was visible near HDP #2 (E-8). The north holddown post blast covers closed normally.

A dark particle originated from the HDP #4 haunch area and was pulled into the SRB exhaust hole by aspiration (E-7, 15). Another debris object, two inches long, originated from the HDP #7 shoe area and moved in the direction of the SRB nozzle before falling into the SRB exhaust hole without contacting flight hardware (E-11). The aft skirt EPON shim did not appear to be missing any material. Seven thin, dark particles, most likely paint chips from the FSS, fell into the field of view near the camera lens (E-13).

Several films showed apparent dark objects falling in the direction of the MLP deck from above (E-14, 18, 26). These objects are shadows cast by falling ice or water drops.

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

Condensate/vapors trailed from the split in the rudder speed brake (E-52).

Numerous (over 100) particles fell out of the RH SRB plume during and after the roll maneuver (E-59, 207).

Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters as pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings (E-212, 220, 222).

A light colored object first appeared (GMT 13:07:37.596) from an area behind the LH RCS stinger near the Orbiter aft fuselage and fell into the SRB plume. The object was most likely an RCS thruster paper cover (E-52, 222, TV-21B).

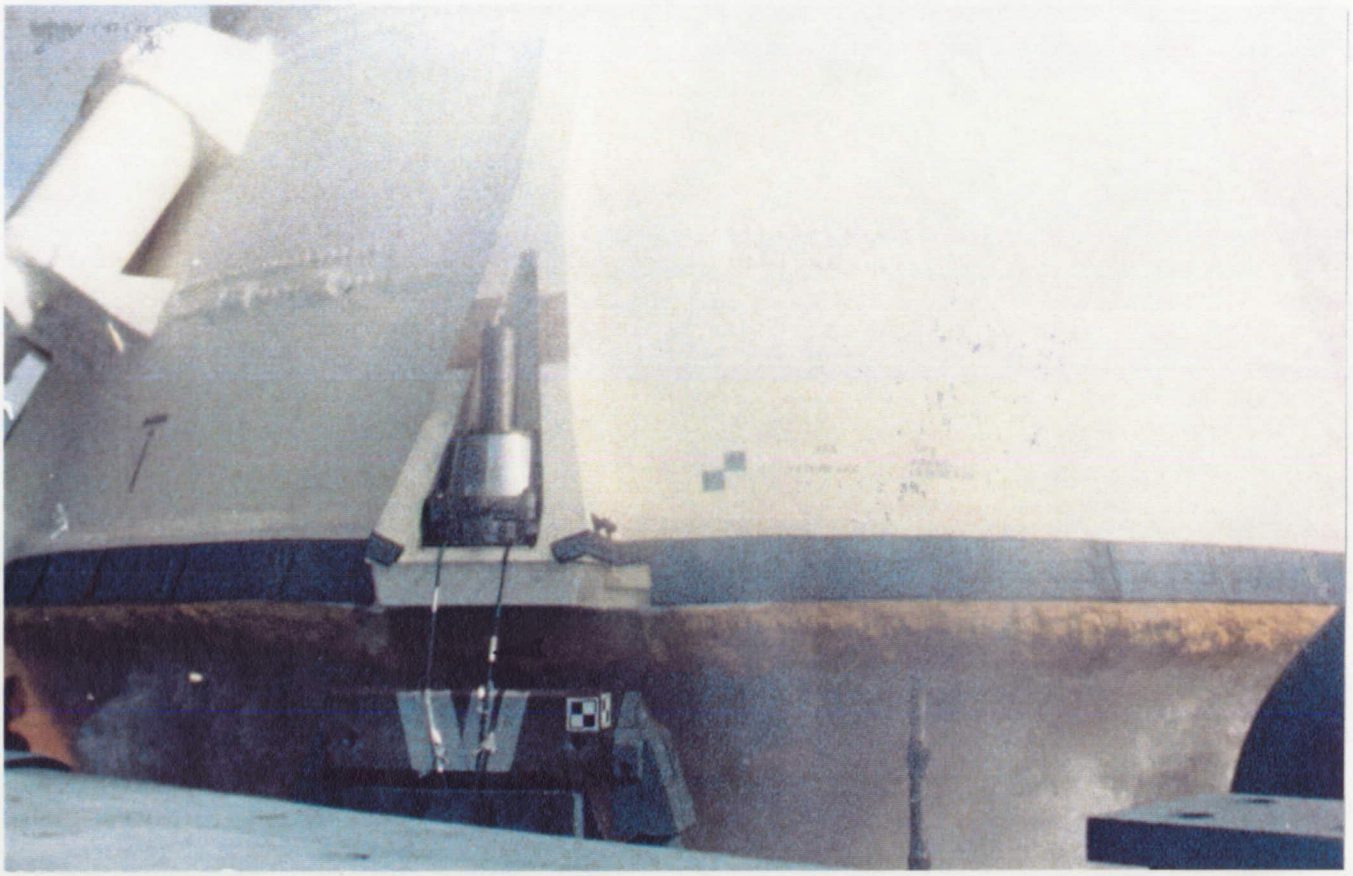
Flashes, most likely debris-induced, occurred in the SSME plume during ascent (E-222, ET-204, ET-212).

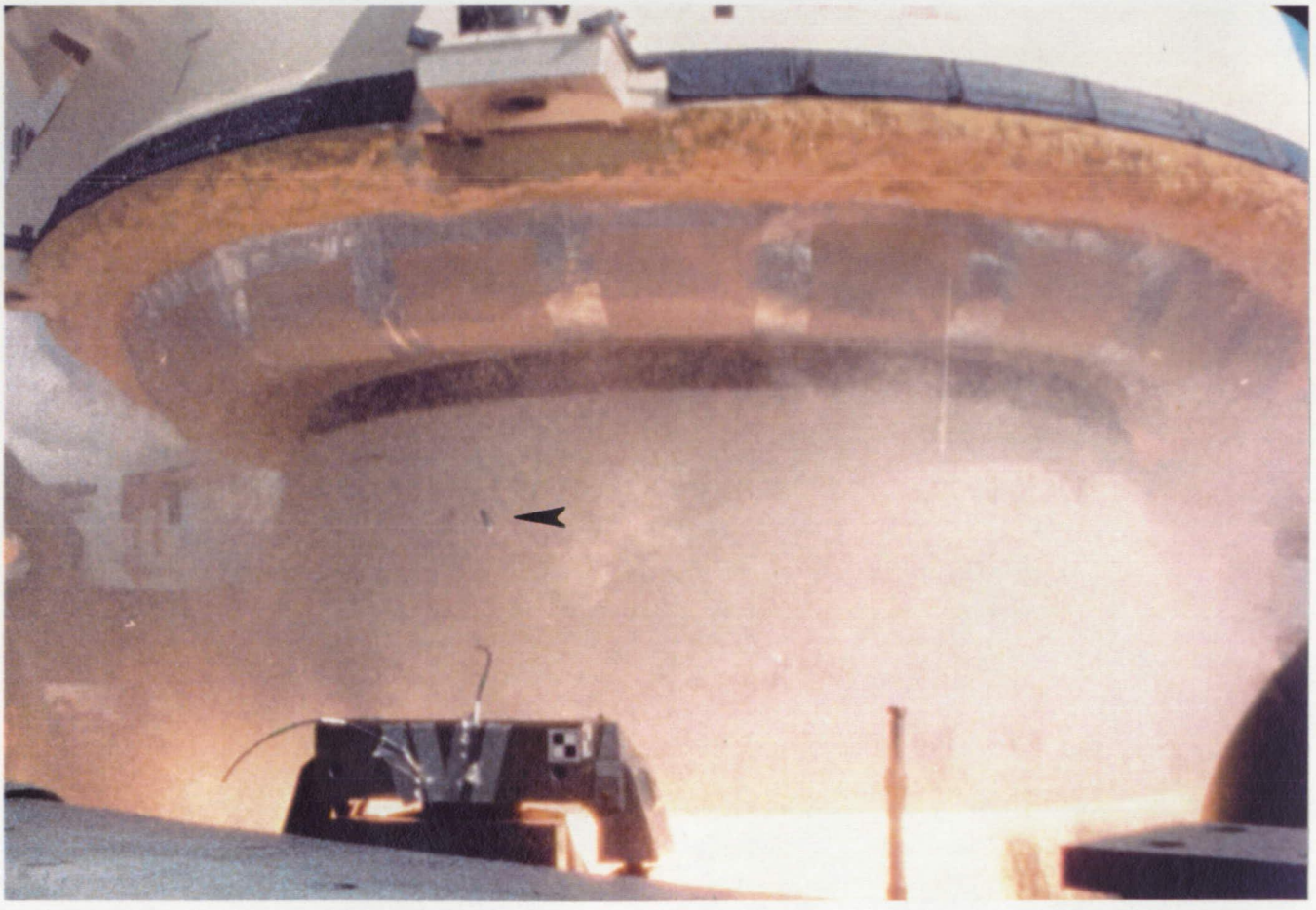
Movement of the body flap was similar to previous flights (E-207, 212).

Local flow condensation at various points on the vehicle was typical but distinctly visible due to the ambient atmospheric conditions (E-207, 208, 220, 222, TV-4B, TV-5, TV-13).

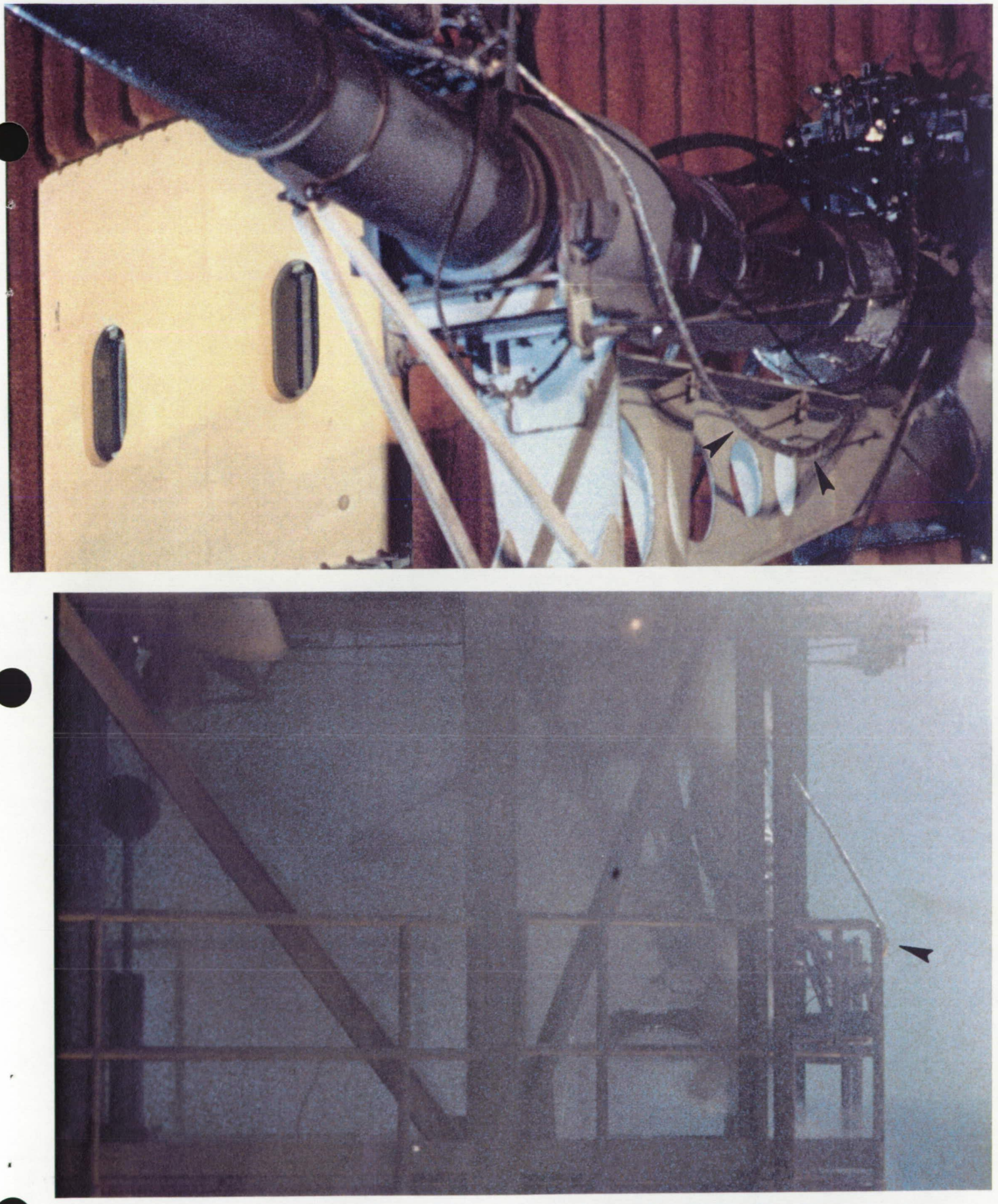
Exhaust plume recirculation and SRB separation appeared nominal (E-208, 212, TV-4B).

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





Two frangible nut pieces fell from the HDP #2 DCS/stud hole after liftoff.



Excessive slack on the cable attached to the GUCP J2 electrical connector caused the cable to momentarily catch on an intertank access platform hand rail during retraction.

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

Thirty-seven handheld still images (DTO-0312) and video were obtained of the ET after separation from the Orbiter by the flight crew. OV-105 was equipped to carry two umbilical cameras. The 16mm camera with the 10mm lens was not flown in the ET/ORB LH2 umbilical due to a structural interference problem.

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

SRB separation from the ET was nominal. No anomalies were observed on the LH SRB segment cases and joints, forward skirt, and frustum. The left forward BSM aero heat shield covers were fully opened and latched.

ET separation from the Orbiter appeared nominal. Pieces of ice, frozen hydrogen, and foam drifted by the ET/ORB LH2 umbilical camera. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, LO2 tank acreage, LH2 tank acreage, PAL ramps, RSS antennae, flight door, bipod ramps, aft hard point, and aft dome acreage. Exhaust plume recirculation and aft dome heating caused the usual charring and "popcorning" of the NCFI foam.

The lightning contact strip was missing from the top of the LO2 ET/ORB umbilical (the others were intact). TPS damage had occurred on the top inboard section of the umbilical. Foam was missing from the top, bottom, and outboard sides of the cable tray (horizontal section). Eight TPS divots were visible in the cable tray vertical section.

The red purge seal was missing from the LH2 ET/ORB umbilical near the 4-inch disconnect (still attached to the Orbiter after landing) and at the top outboard section. A piece of white RTV drifting by the camera lens may also have originated from the top outboard section. TPS damage had occurred on the inboard side of the umbilical and a large piece of foam, which measured approximately 2 feet long by 4 inches wide by as much as 1 inch thick, had partially separated from the umbilical. TPS on the top surface of the umbilical had peeled back in two places.

The red seals at both EO fittings (EO-2 and EO-3) were loose and dangling by the retaining cords.

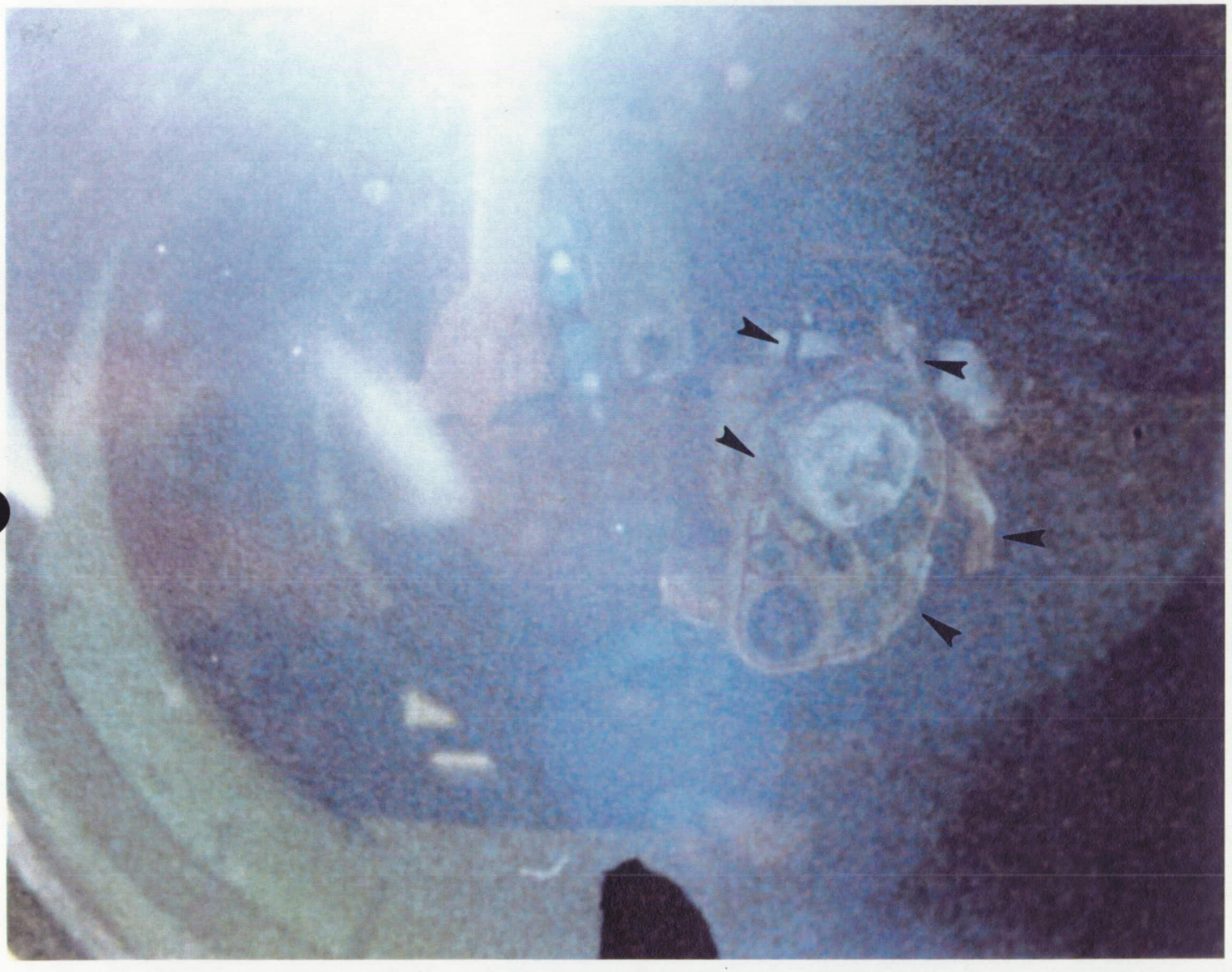
A divot, 6-8 inches in diameter, was present in the -Y (LH) longeron closeout.

Foam was missing from the +Y thrust strut flange and primer/ metal substrate was exposed.

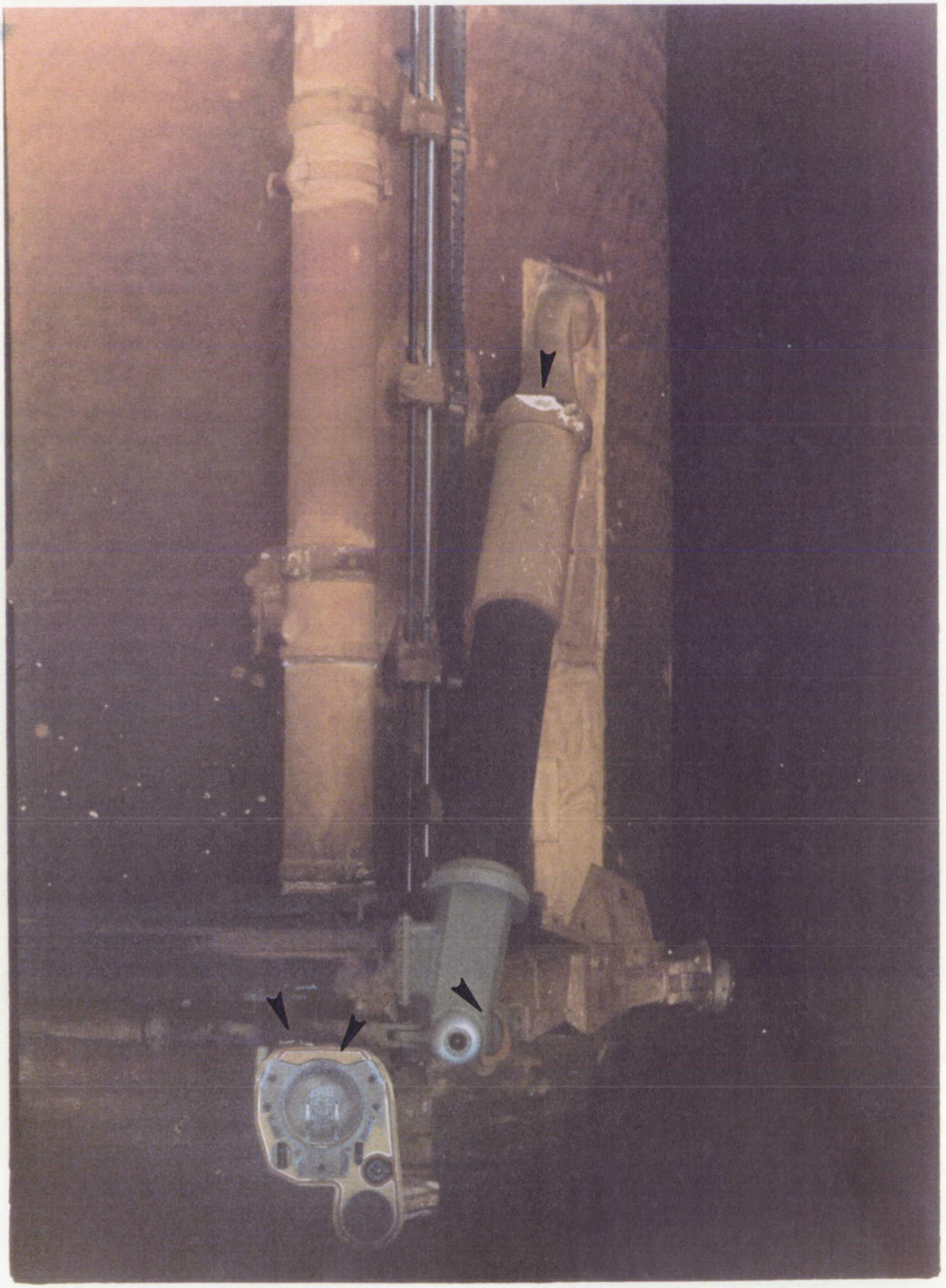
Three divots were present in the LH2 tank-to-intertank flange closeout +Y+Z quadrant: one near the LO2 feedline; two below the +Y EB fitting. A divot, 10 inches in diameter, was present in the -Y+Z quadrant flange closeout below the -Y EB fitting with another divot, 6 inches in diameter, nearby in the -Y thrust panel acreage. An 8 inch divot was visible in the flange closeout near the -Z axis.

At least 70 small divots, 3-4 inches in diameter, occurred on intertank stringers forward of the bipods. Seven small divots were visible in the LH2 tank-to-intertank flange closeout between the bipods. Both +Y and -Y bipod ramps and jack pad closeouts were intact.

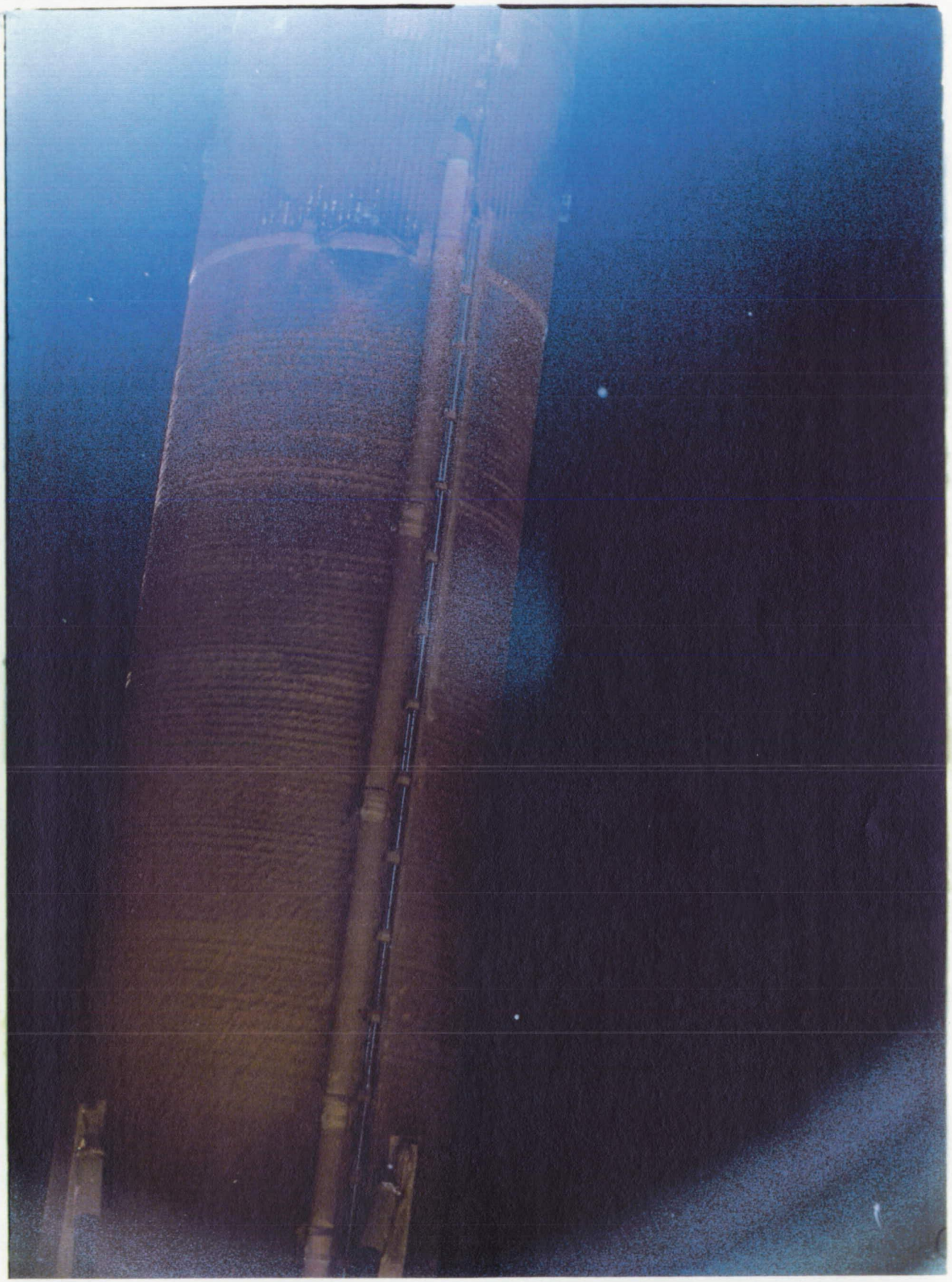
Nine divots, 6-8 inches in diameter, occurred along a line on the -Y thrust panel on the +Z side of the EB fitting. As many as nine smaller divots were scattered on the -Y thrust panel on the -Z side of the EB fitting (Add to existing IFA).



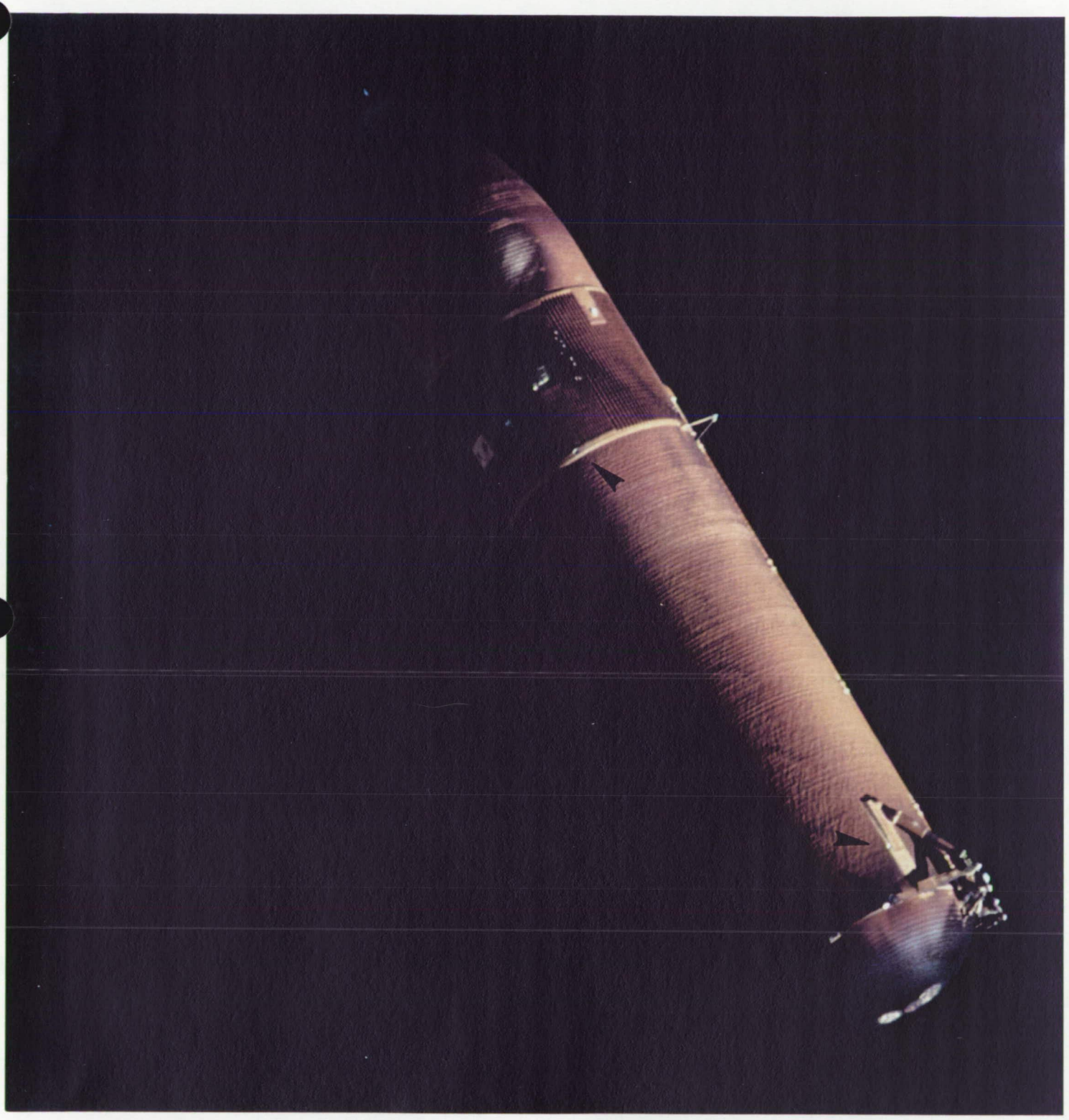
The red purge seal was missing from the ET/ORB LH2 umbilical near the 4-inch disconnect and at the top outboard section. TPS was damaged on the inboard side of the umbilical and a large piece of foam, which measured approximately 2 feet long by 4 inches wide by as much as 1 inch thick, had partially separated from the umbilical. TPS on top of the umbilical had peeled back in two places.



The lightning contact strip was missing from the top of the LO2 ET/ORB umbilical (the others were intact). TPS was damaged on the top inboard side of the umbilical. The red seal at the EO fitting was loose and dangling by the retaining cord. Foam was missing from the +Y thrust strut flange and primer/metal substrate was exposed.



At least 70 small divots, 3-4 inches in diameter, occurred on the intertank stringers forward of the bipods. Seven small divots were visible in the LH2 tank-to-intertank flange closeout between the bipods.



Nine divots occurred in a rough line along the edge of the -Y thrust panel. A divot is visible in the LH2 tank-to-intertank flange closeout and the -Y longeron closeout. There were no TPS anomalies on the LH2 and LO2 tank acreage.

6.3 LANDING FILM AND VIDEO SUMMARY

A total of nine 35mm large format films, seven 16mm high speed films, and 10 videos were reviewed.

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

The drag chute was deployed just after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal though the parachute risers contacted a tile on the vertical stabilizer "stinger". The drag chute door appeared to get caught in the RH wing tip vortex and landed near the east edge of the runway. A crosswind blew the drag chute to the right of the Orbiter centerline.

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

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 23 June 1993 from 0900 to 1100 hours. From a debris standpoint, both SRB's were in good condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had 46 MSA-2 debonds over fasteners and two areas of missing MSA-2 (between the 275 and 318 ring frames near the -Y axis). Minor blistering of the Hypalon paint had occurred in localized areas (Figure 5). All BSM aero heat shield covers were locked in the fully opened position, though the two left cover attach rings had been bent by parachute riser entanglement.

The RH forward skirt acreage was missing no TPS, but had one MSA-2 debond near the forward attach fitting. Both RSS antennae covers/phenolic base plates were intact though the -Z plate had delaminated (Figure 6). Minor blistering of the Hypalon paint occurred on the systems tunnel cover and around the ET/SRB attach point. No pins were missing from the frustum severance ring. The forward separation bolt appeared to have separated cleanly.

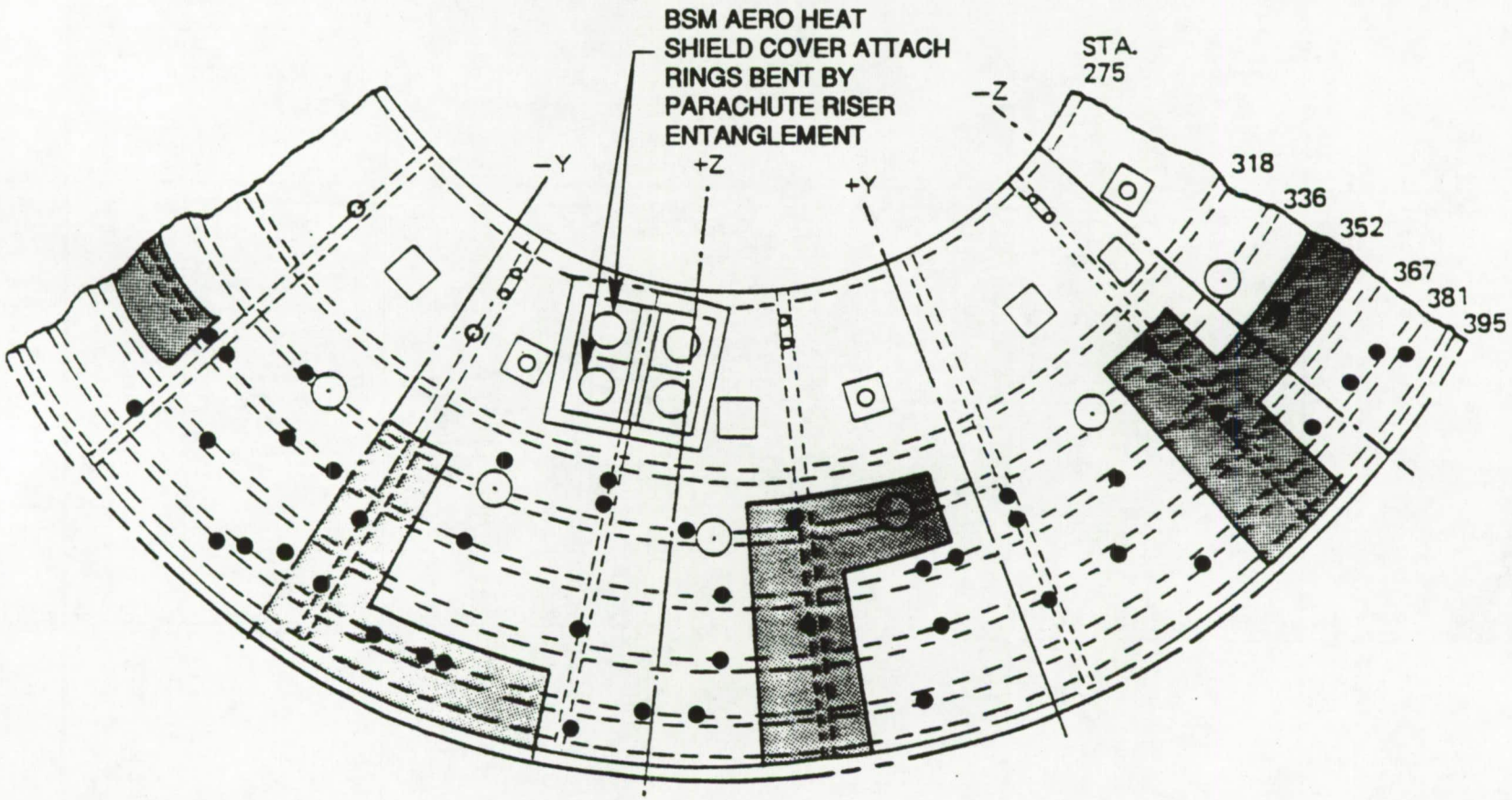
The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension. Paint was missing from several areas on the forward segment.

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

The phenolic material on the kick ring was delaminated. The K5NA closeouts (protective domes) on the kick ring forward and aft fasteners are no longer used. RTV-133 has replaced the K5NA over the forward fasteners. The aft skirt acreage TPS was generally in good condition but was missing a 4"x3" piece of MSA-2 on ring frame 1894 fasteners near the single BSM (Figure 7).

All four Debris Containment System (DCS) plungers were seated. No malfunction of the HDP #2 DCS was apparent even though two frangible nut pieces had fallen from the stud hole after lift off (as observed in the film review). None of the EPON shim material was missing prior to water impact.

FIGURE 5. **RIGHT SRB FRUSTUM**



EGG/V-326

FIGURE 6. **RIGHT SRB FWD SKIRT**

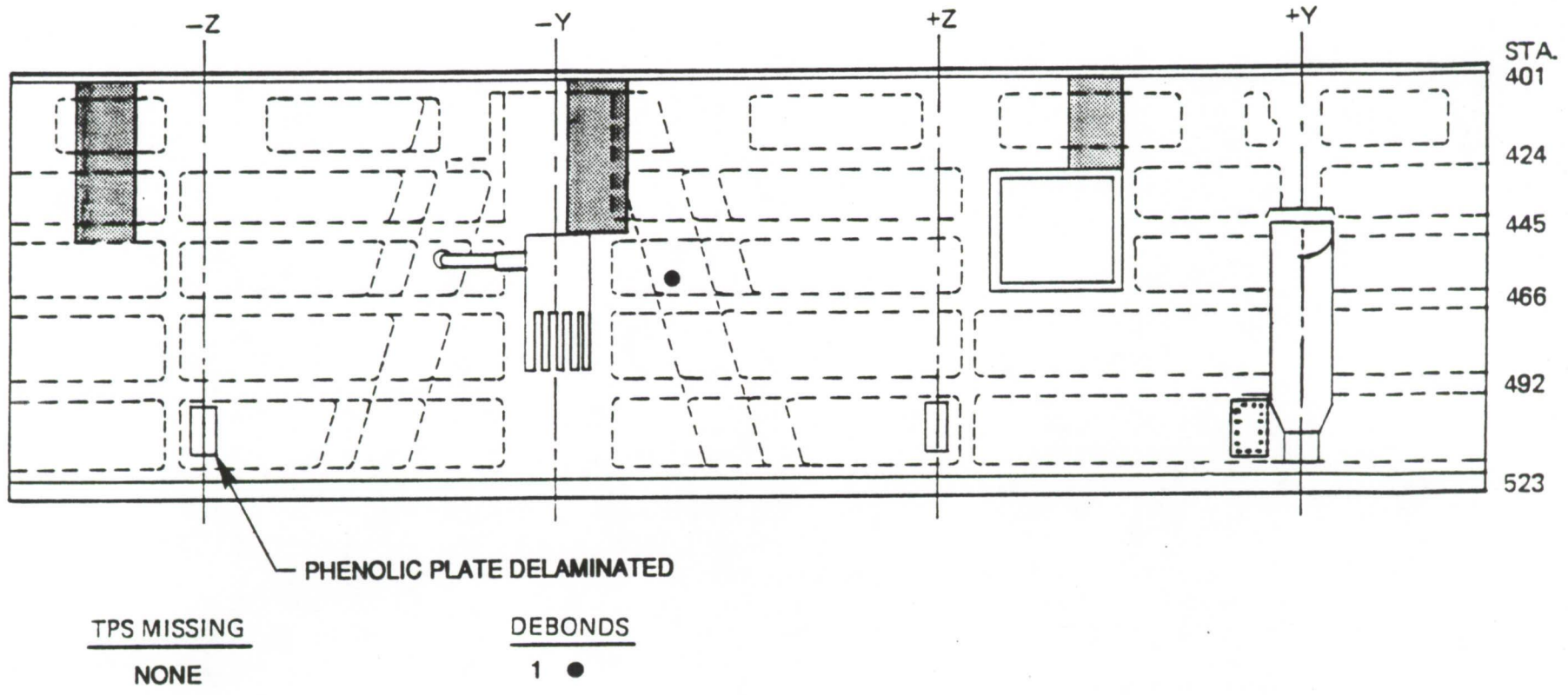
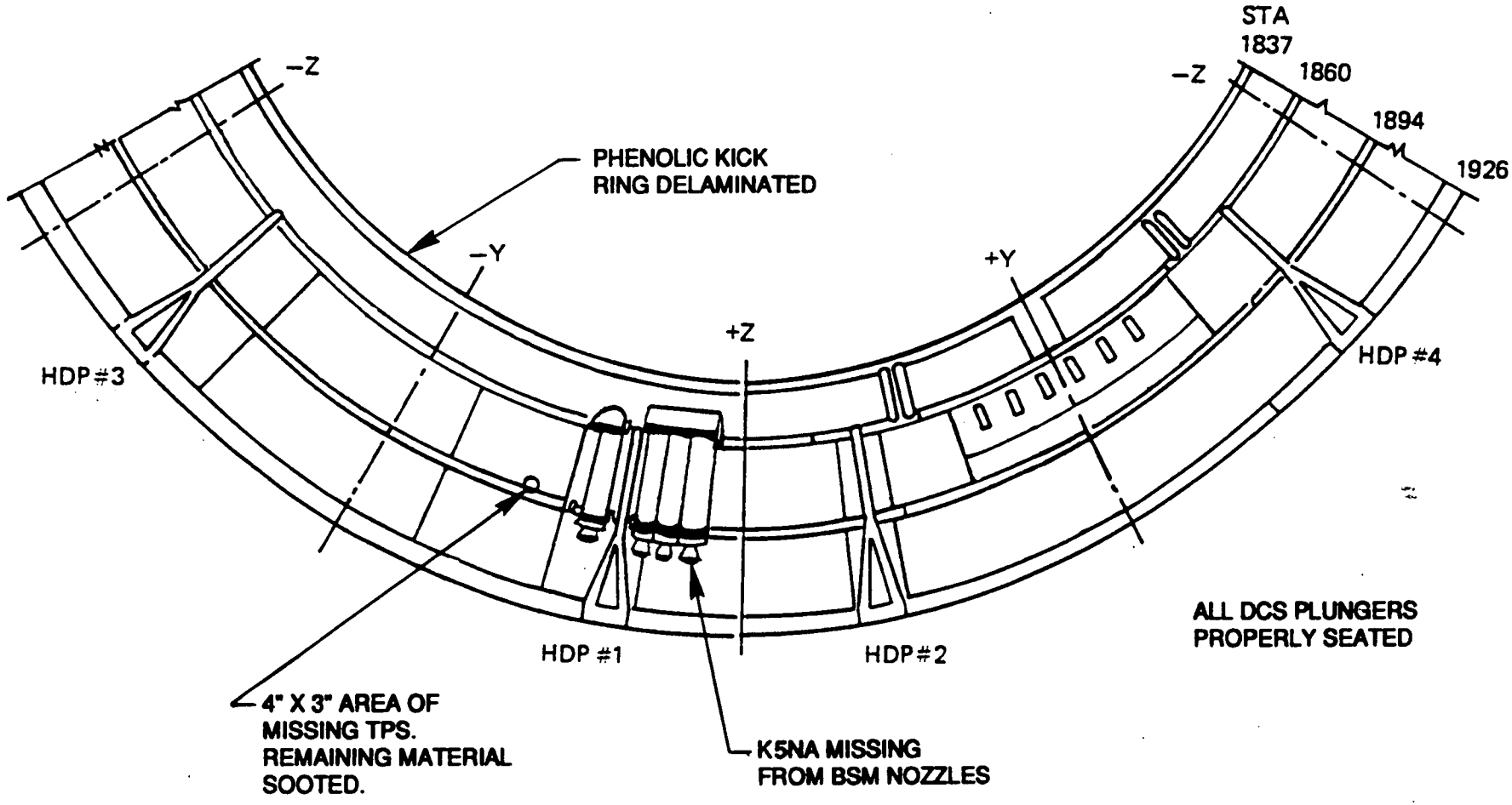
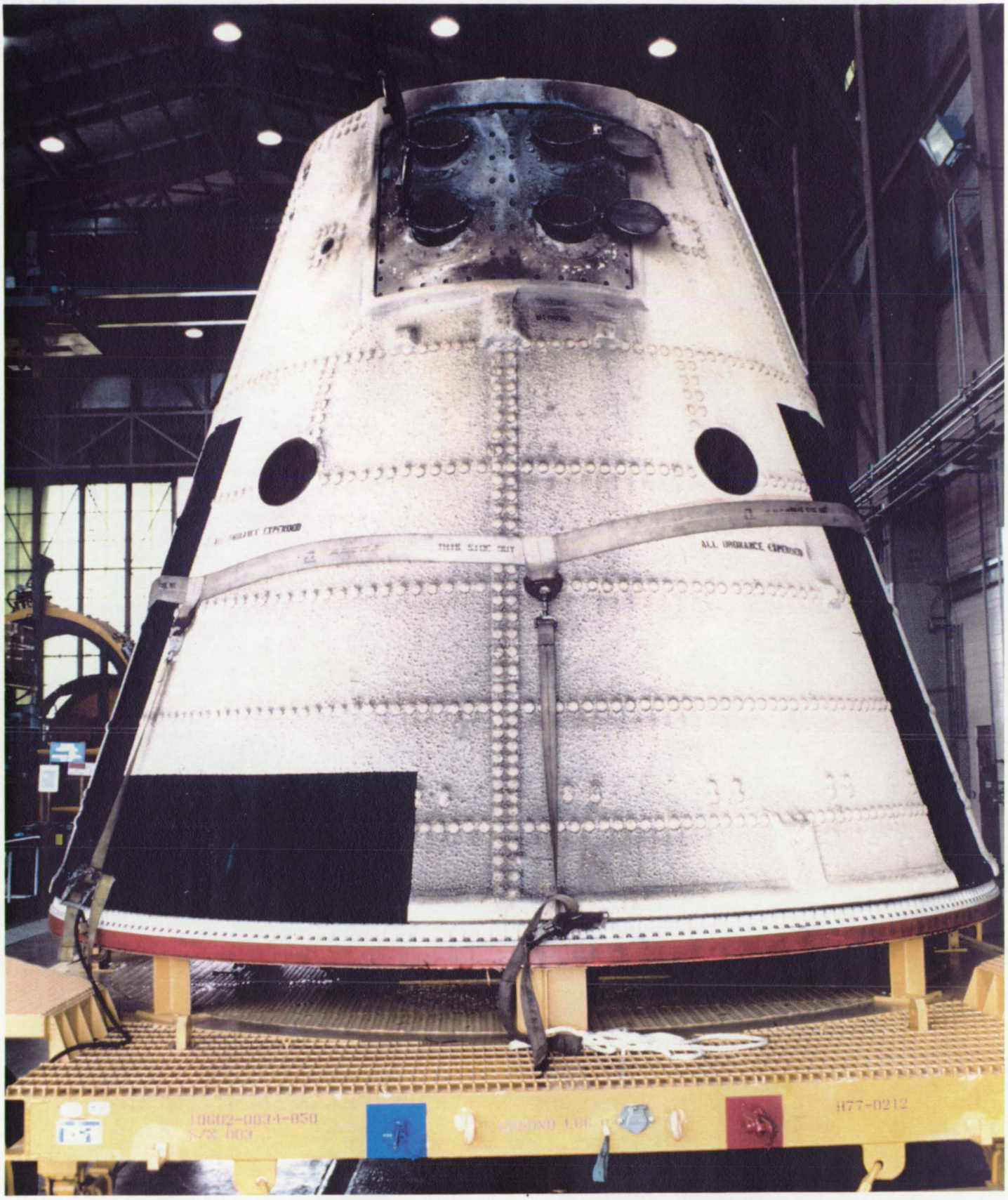


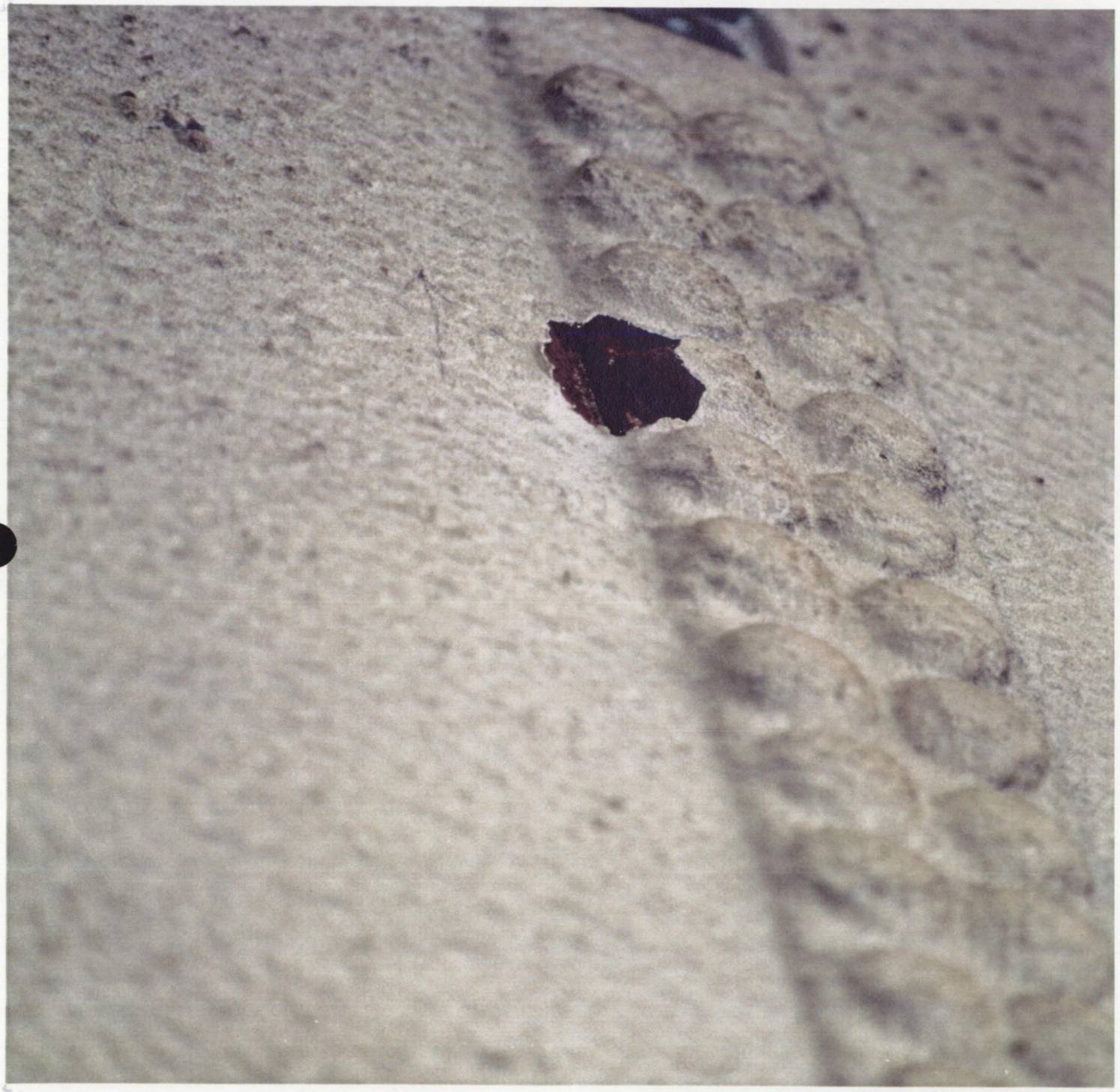
FIGURE 7. **RIGHT SRB AFT SKIRT EXTERIOR TPS**



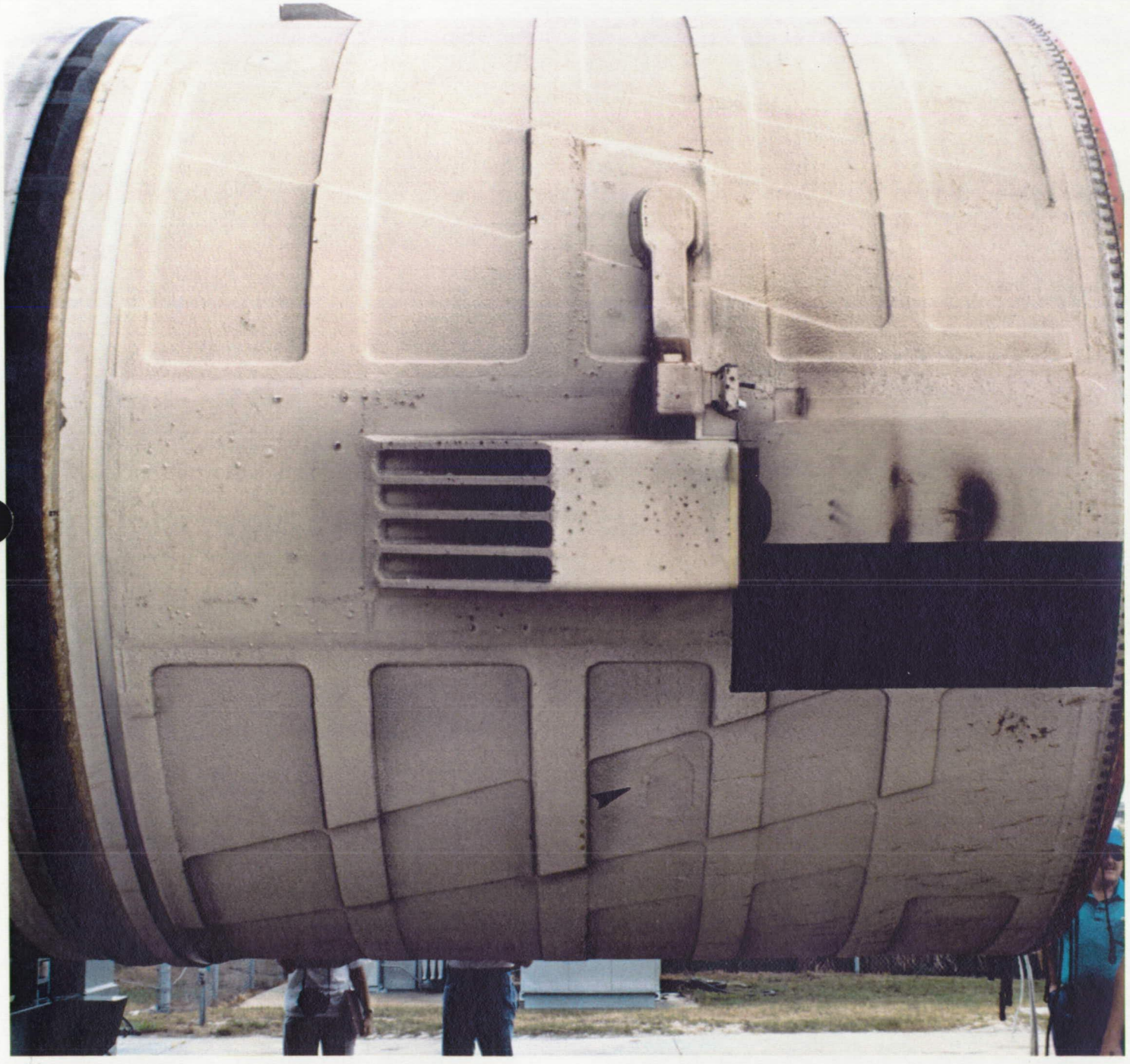
EGG/V 326C



The RH frustum had 46 MSA-2 debonds over fasteners and two areas of missing MSA-2. All BSM aero heatshield covers were locked in the fully opened position, though the two left cover attach rings had been bent by parachute riser entanglement.



Loss of MSA-2 TPS from a frustum fastener



The RH forward skirt acreage MSA-2 was missing no TPS, but had one MSA-2 debond near the forward attach fitting. Both RSS antenna covers/phenolic base plates were intact.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS, but had 27 MSA-2 debonds over fasteners. Minor localized blistering of the Hypalon paint had occurred along the 395 ring (Figure 8). The BSM aero heat shield covers were locked in the fully opened position.

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

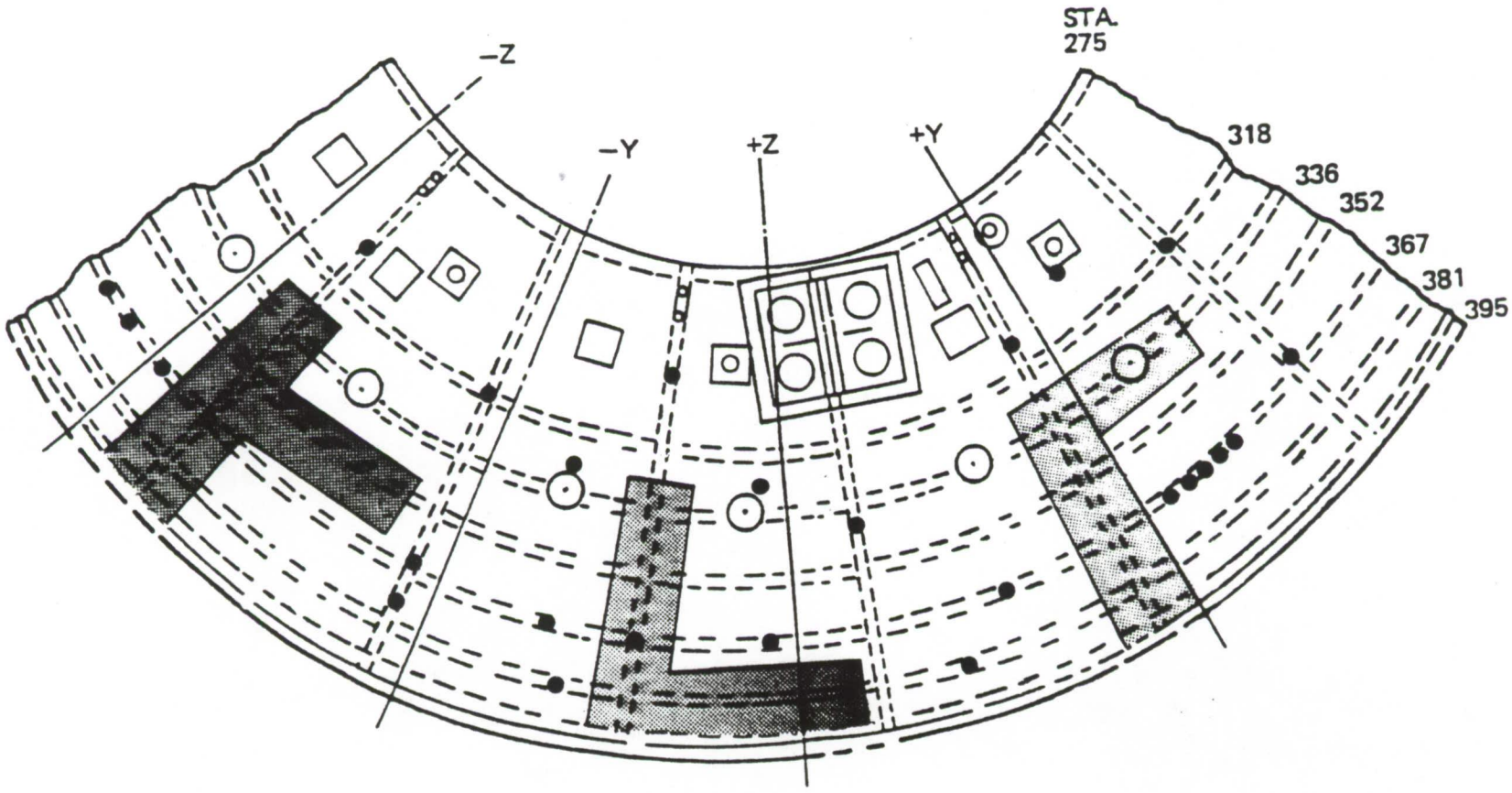
The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension. Paint was missing from eight areas on the aft center segment.

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

The phenolic material on the kick ring was delaminated. The K5NA closeouts (protective domes) on the kick ring forward and aft fasteners are no longer used. RTV-133 has replaced the K5NA over the forward fasteners. One 3"x2" area of MSA-2 was missing from the aft skirt acreage TPS near the 1926 ring frame between the -Y and +Z axes. The remaining material was slightly sooted (Figure 9).

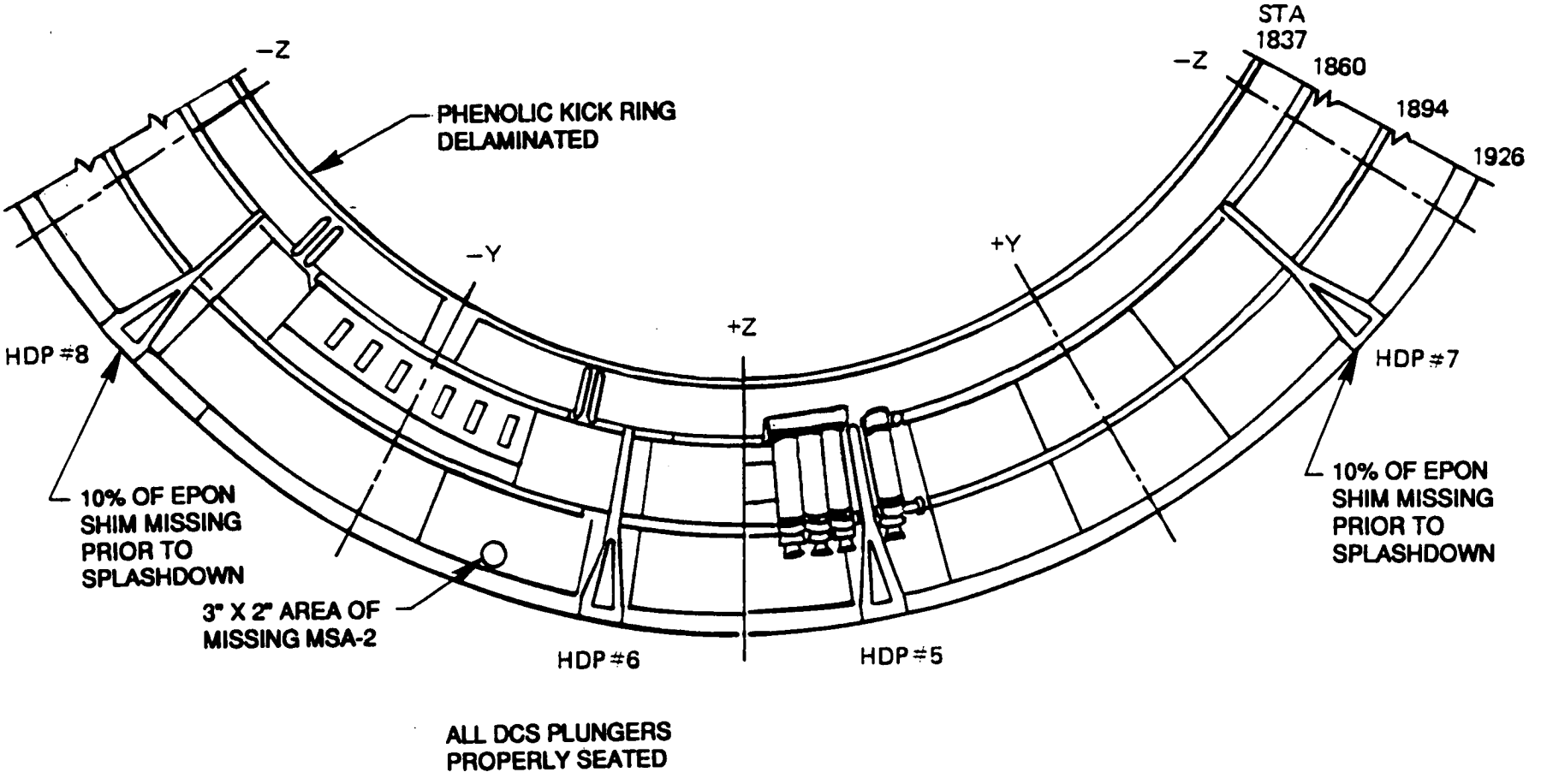
All four Debris Containment System (DCS) plungers were seated. Approximately ten percent of the EPON shim material on both HDP #7 and #8 aft skirt support structure was missing prior to splashdown. The substrates were sooted/charred.

FIGURE 8. **LEFT SRB FRUSTUM**



MISSING TPS	DEBONDS
NONE	27 ●

FIGURE 9. **LEFT SRB AFT SKIRT EXTERIOR TPS**



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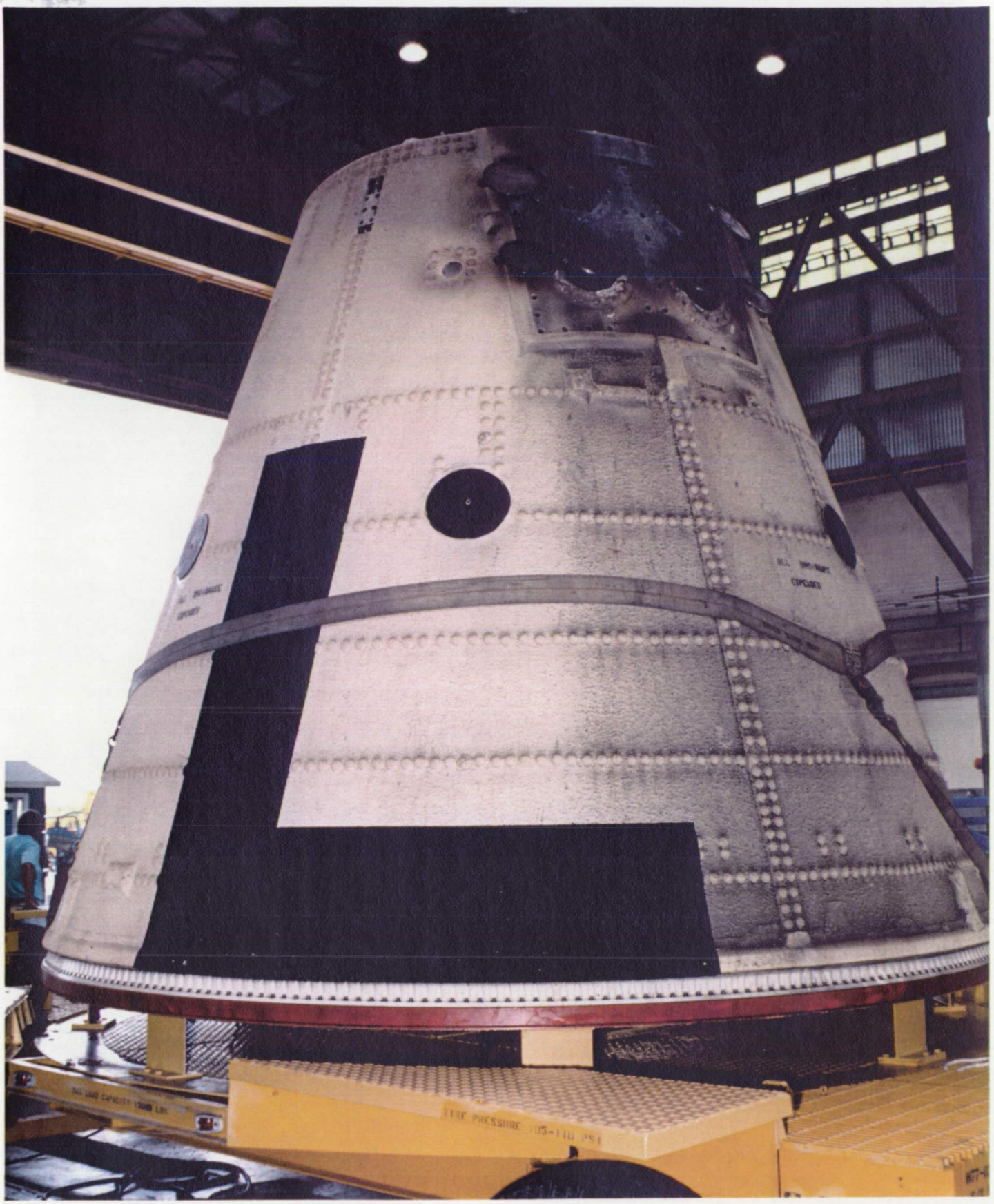
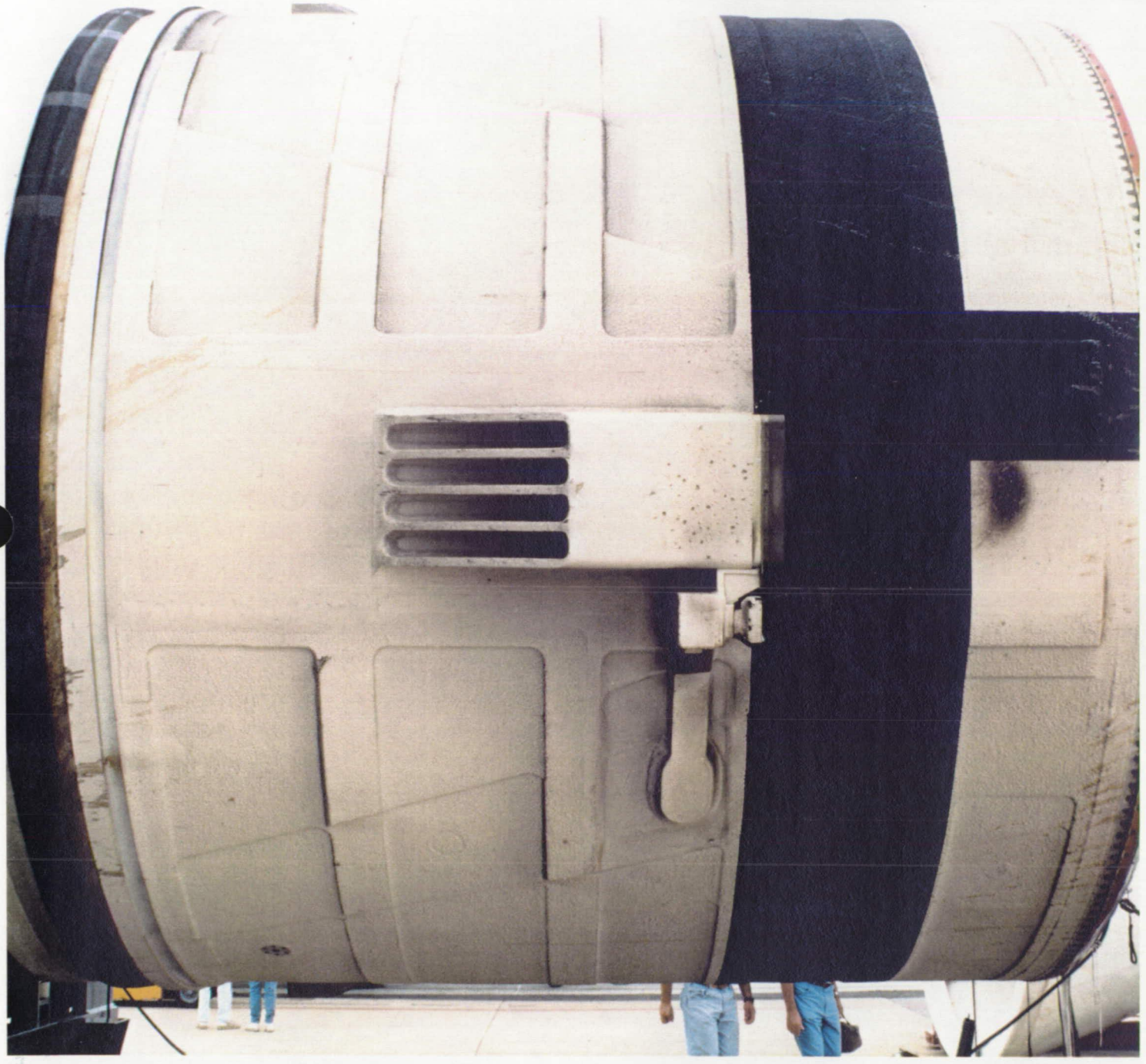
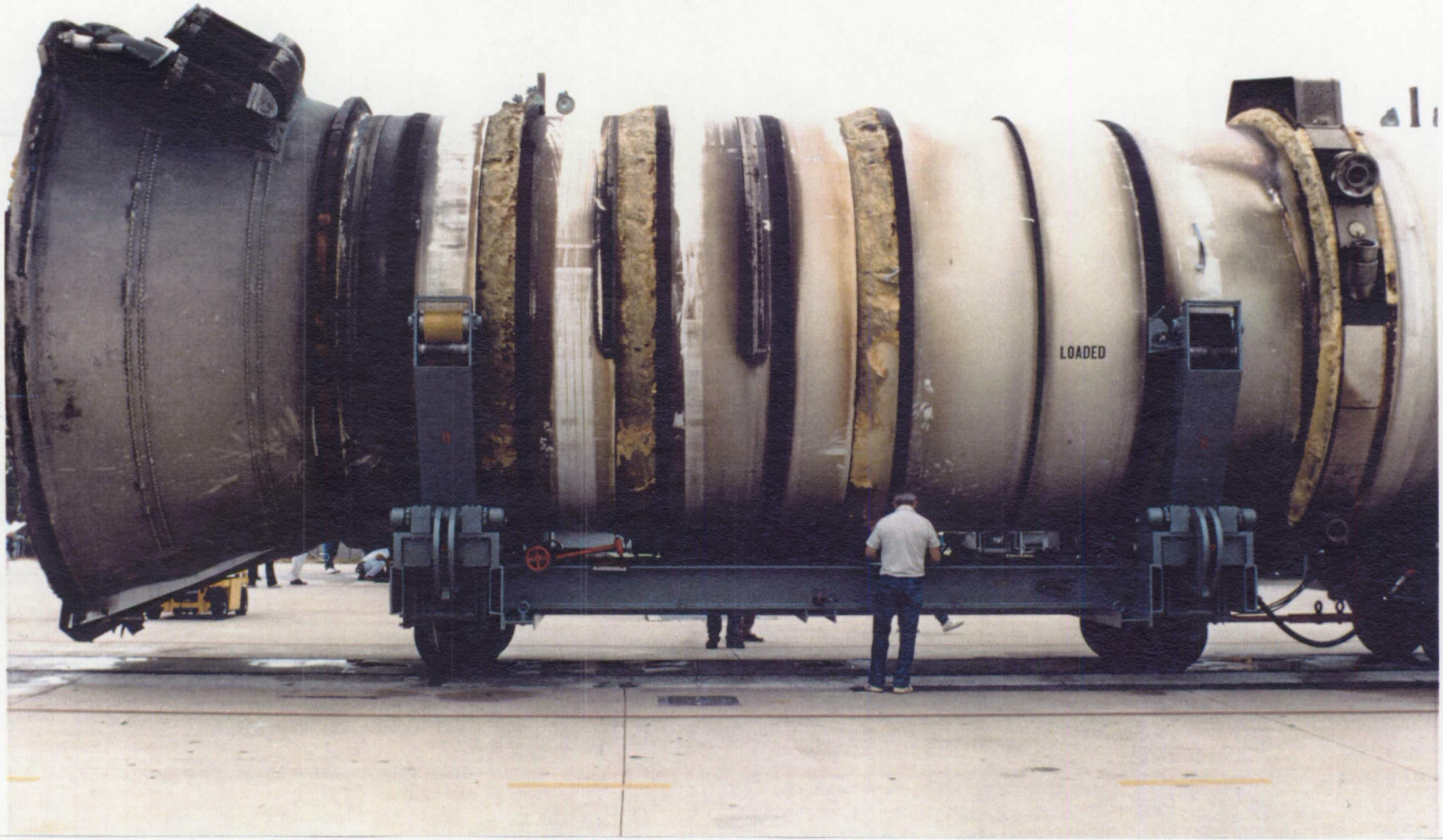


The LH frustum had a total of 27 MSA-2 debonds over fasteners. The BSM aero heat shield covers were locked in the fully opened position.



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 LH aft booster and aft skirt. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. All three aft booster stiffener rings were damaged by water impact.

Approximately ten percent of the EPON shim material was missing prior to splashdown. The substrate was sooted.

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

STS-57 was the sixteenth flight to utilize the new "optimized" frangible links in the holddown post DCS's. The link was designed to increase the DCS plunger velocity and improve the seating alignment while leaving the stud ejection velocity the same. The design was intended to prevent ordnance debris from falling out of the DCS yet not increase the likelihood of a stud hang-up. According to NSTS-07700, the Debris Containment System should retain a minimum of 90 percent of the ordnance debris.

A recent change to the disassembly procedures by SRB Project (DCN 009 10MNL-0035) eliminated the weighing of frangible nut pieces and ordnance fragments in the DCS containers unless: 1) debris is observed in the launch films; 2) the DCS plunger has an anomalous appearance during disassembly; or, 3) visual inspection of the expected DCS contents reveals the absence of any pieces.

High speed launch film showed the loss of two frangible nut pieces from the HDP #2 DCS at liftoff. Due to this anomaly, the contents of the DCS #2 housing was weighed. A total of 1.165 pounds of debris were lost sometime after launch.

HDP #	% of Nut without 2 Large Halves	% of Ordnance Fragments	% Overall
2	5	21	11

SRB Post Launch Anomalies are listed in Section 10.

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-105 (Endeavour) was conducted 1-2 July 1993 at the Kennedy Space Center on Shuttle Landing Facility (SLF) runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 106 hits, of which 12 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 40 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 is less than average (reference Figures 10-13).

The Orbiter lower surface sustained a total of 75 hits, of which 10 had a major dimension of one inch or greater. The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

The following table breaks down the STS-57 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	10	75
Upper surface	1	21
Right side	0	3
Left side	1	2
Right OMS Pod	0	3
Left OMS Pod	0	2
TOTALS	12	106

The largest tile damage site measured 3.5" x 0.75" x 0.375" and was located on the RH lower surface outboard of the nose landing gear door.

A cluster of 8 hits with maximum depths of 0.375 inches just forward of the LH2 ET/ORB umbilical may be indicative of impacts from higher density materials, such as ice.

No anomalies were noted on the RCC nosecap or wing leading edge panels. However, AFRSI blankets near the F3D and F1F thrusters were discolored.

FIGURE 10. **DEBRIS DAMAGE LOCATIONS**

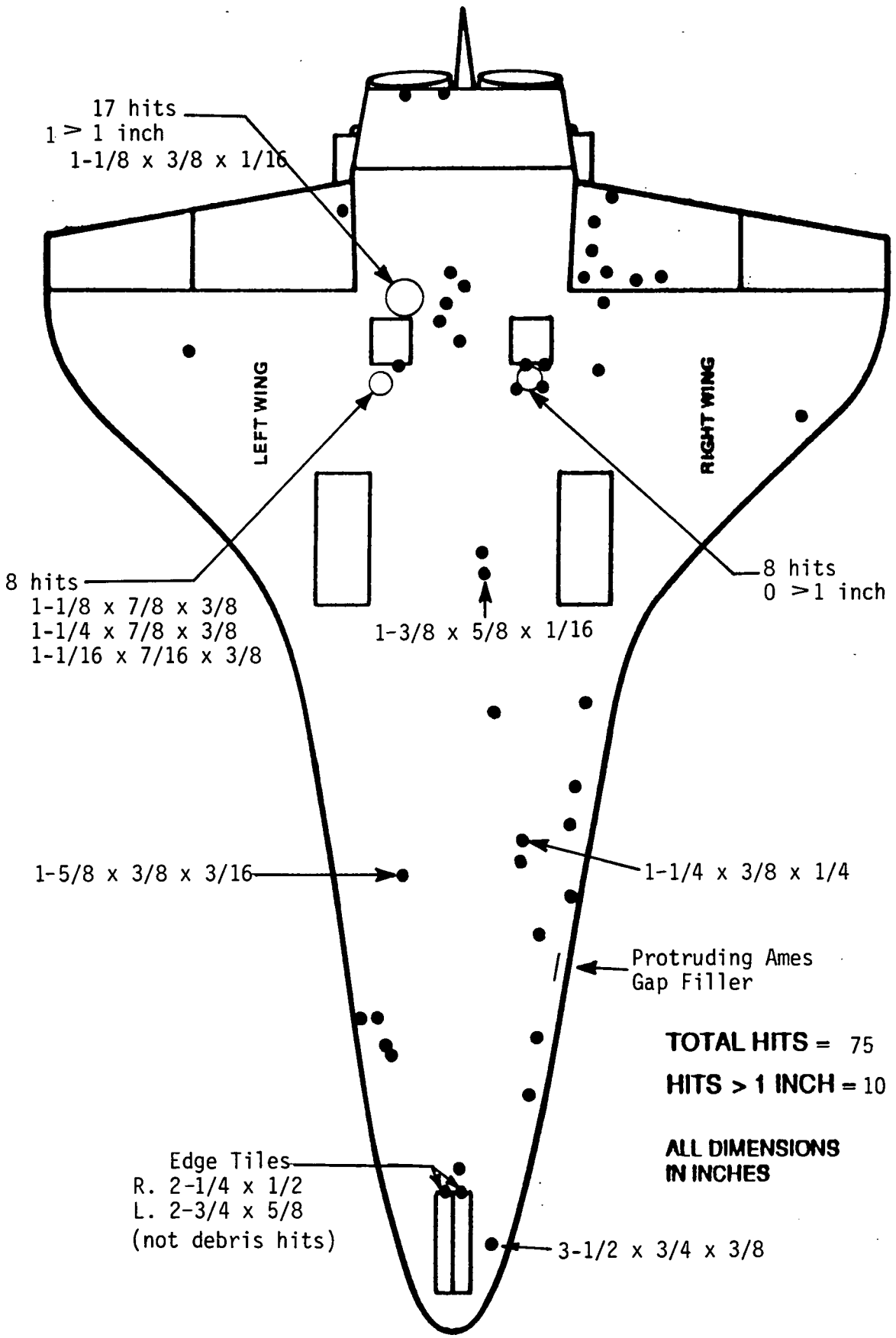


FIGURE 11. **DEBRIS DAMAGE LOCATIONS**

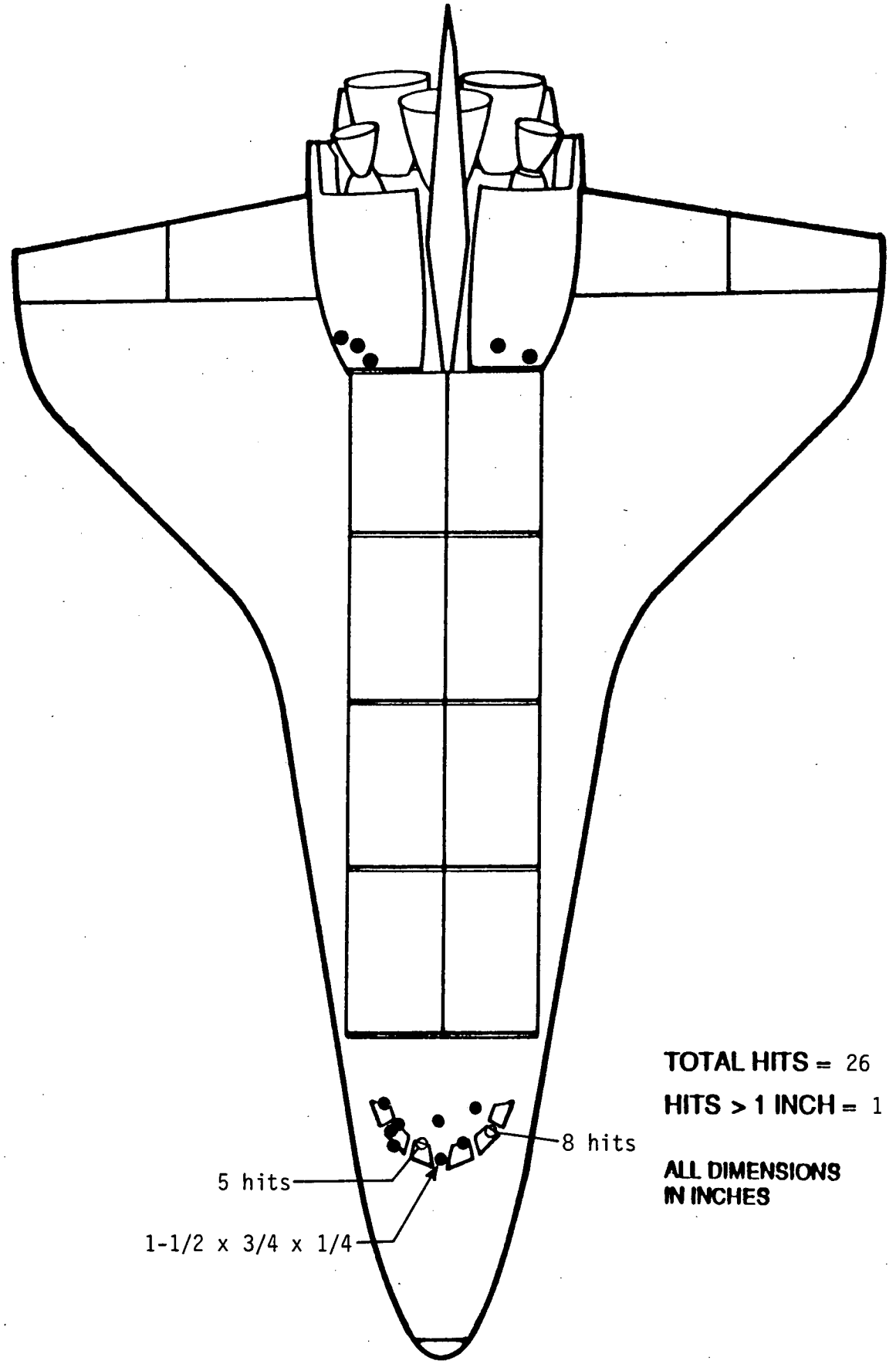
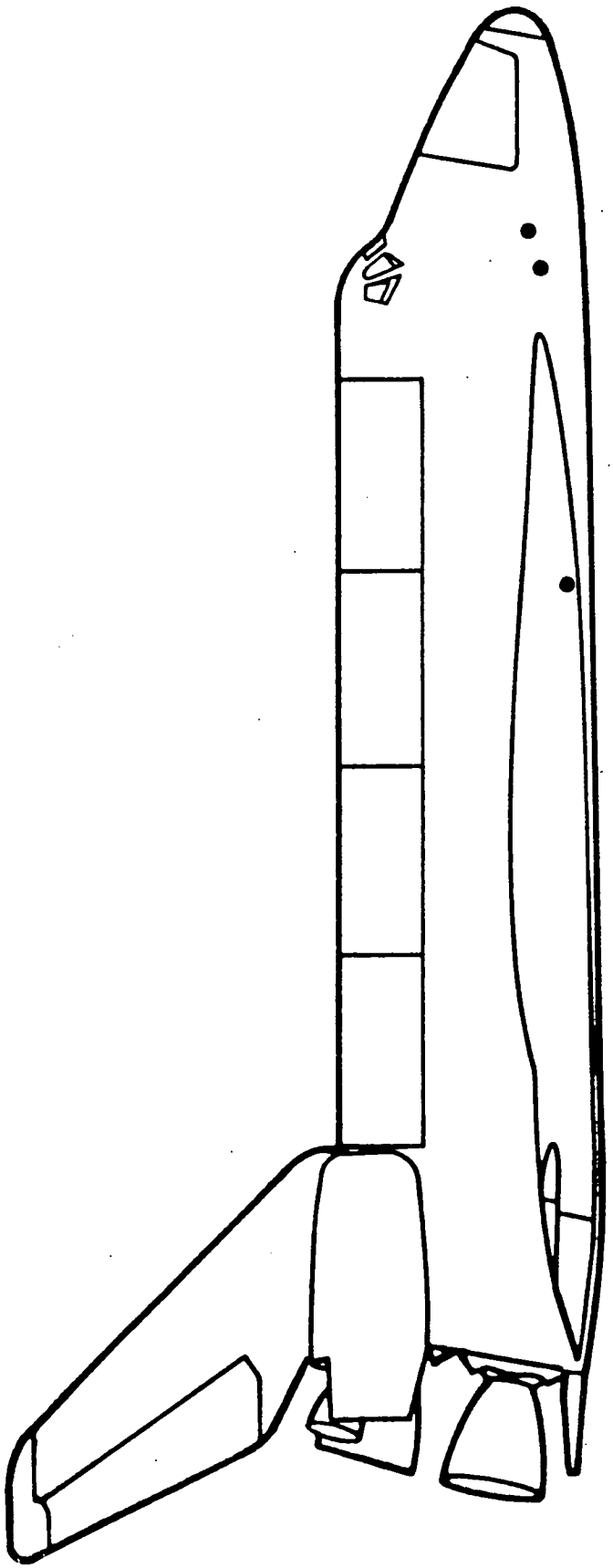


FIGURE 12

STS-57 DEBRIS DAMAGE LOCATIONS

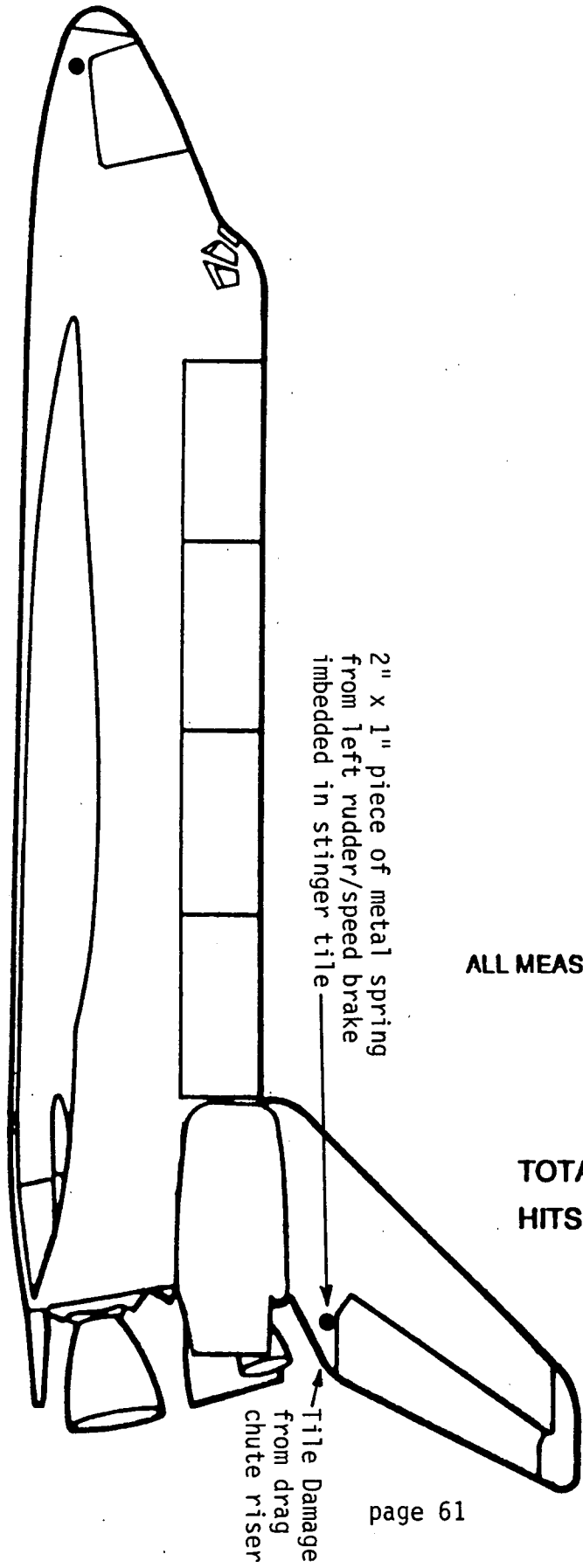


TOTAL HITS = 3

HITS > 1 INCH = 0

FIGURE 13

STS-57 DEBRIS DAMAGE LOCATIONS



ALL MEASUREMENTS IN INCHES

TOTAL HITS = 2

HITS > 1 INCH = 1

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires were considered to be in good condition for a landing on the KSC runway.

ET/Orbiter separation devices EO-1 and EO-3 appeared to have functioned properly. The EO-2 debris plunger was obstructed by ordnance fragments. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly.

A 15-inch long piece of LH2 ET/ORB umbilical foam with red silicone sponge purge seal, which should have remained with the ET during separation, adhered to the Orbiter half of the umbilical near the 4-inch flapper valve. Post landing analysis revealed the foam fractured during ET separation and concluded there was an inadequate RTV dam to prevent foam adherence to the curtain attach plate.

A 7/16" x 3/32" screw from the purge barrier retainer lay on the runway below the LH2 ET/ORB umbilical cavity. A nutplate with threads matching the screw was found wedged in a cavity on the ET door.

A piece of foam 3-inches long adhered to a tile on the RH ET door near the hinge line. The foam had been compressed into the thermal barrier when the door was closed, but apparently did not affect the seal during re-entry. According to post flight laboratory analysis, the foam did not match the External Tank acreage thermal protection system (TPS) CPR and was most likely MBO foam from the umbilical.

Orbiter windows #2, #3, #4, and #5 exhibited moderate hazing. Only a very light haze was present on the other windows. Some streaks were visible on windows #2, #3 and #4. Surface wipes were taken from all windows for laboratory analysis.

No samples were taken from tile damage sites or RCC panels.

Tile damage on the base heat shield was average. The SSME Dome Mounted Heat Shield (DMHS) closeout blanket sacrificial panels were intact, missing no material, and in excellent condition. One tile at the aft edge of the vertical stabilizer stinger was damaged by contact with the drag chute risers. A 2" x 1" piece of metal spring from the inside left surface of the rudder/speed brake was embedded in a vertical stabilizer stinger tile near the rudder hinge.

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

The post landing walkdown of Runway 33 was performed immediately after landing. All Orbiter drag chute hardware was recovered. No organic (bird) debris or other hardware was found on the runway.

This flight marked the eighth use of the Orbiter drag chute. Aside from the damage to the vertical stabilizer stinger tile, the drag chute appeared to have functioned nominally. All drag chute hardware appeared to be in good condition.

The Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas on the vehicle (per OMRSD V09AJ0.095). Twenty-one minutes after landing, the Orbiter nosecap RCC was 179 degrees F. Twenty-four minutes after landing, the RH wing leading edge RCC panel #9 was 140 degrees and panel #17 was 127 degrees F (reference Figure 14).

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

Orbiter Post Launch Debris Anomalies are listed in Section 10.0.

FIGURE 14. **STS-57 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

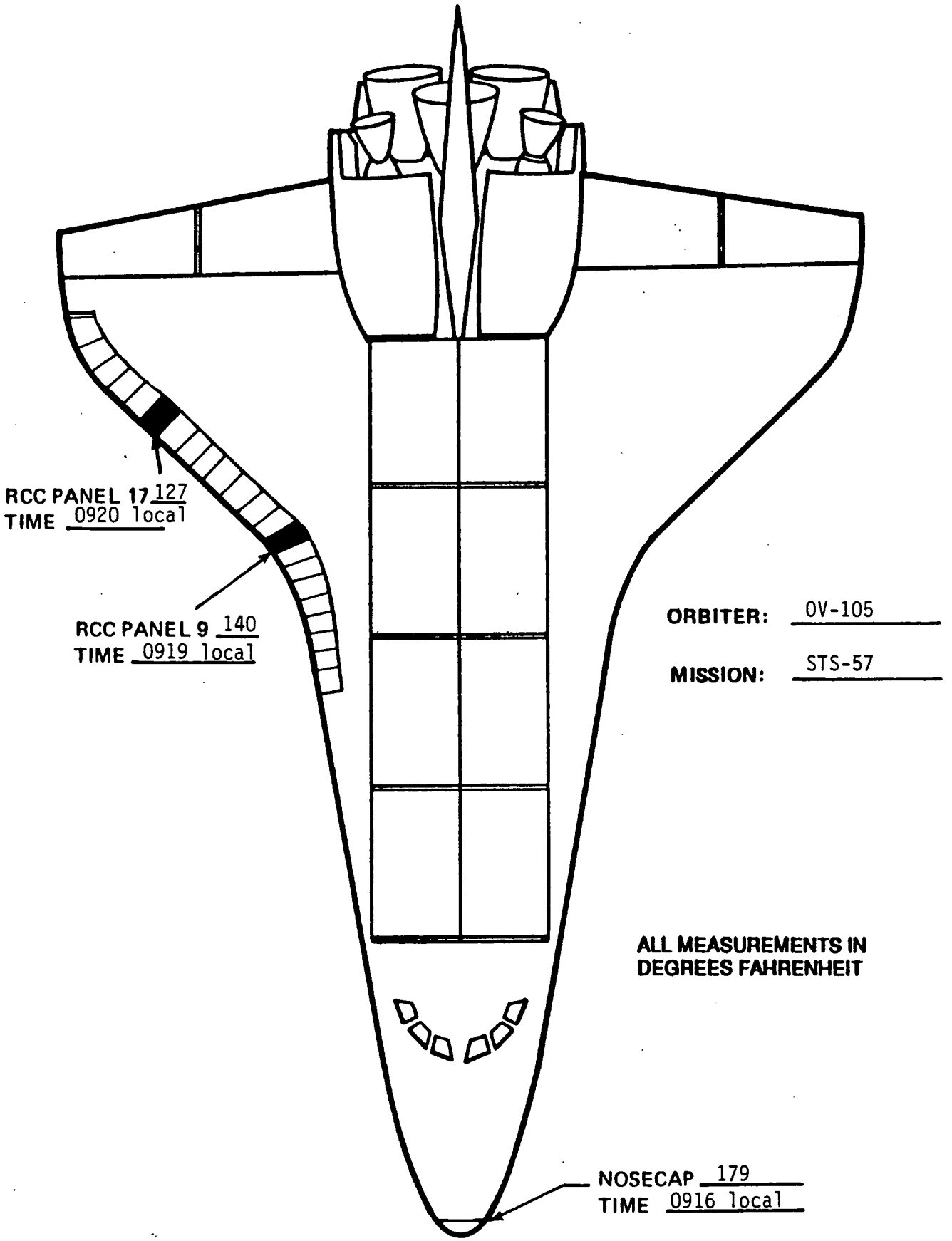


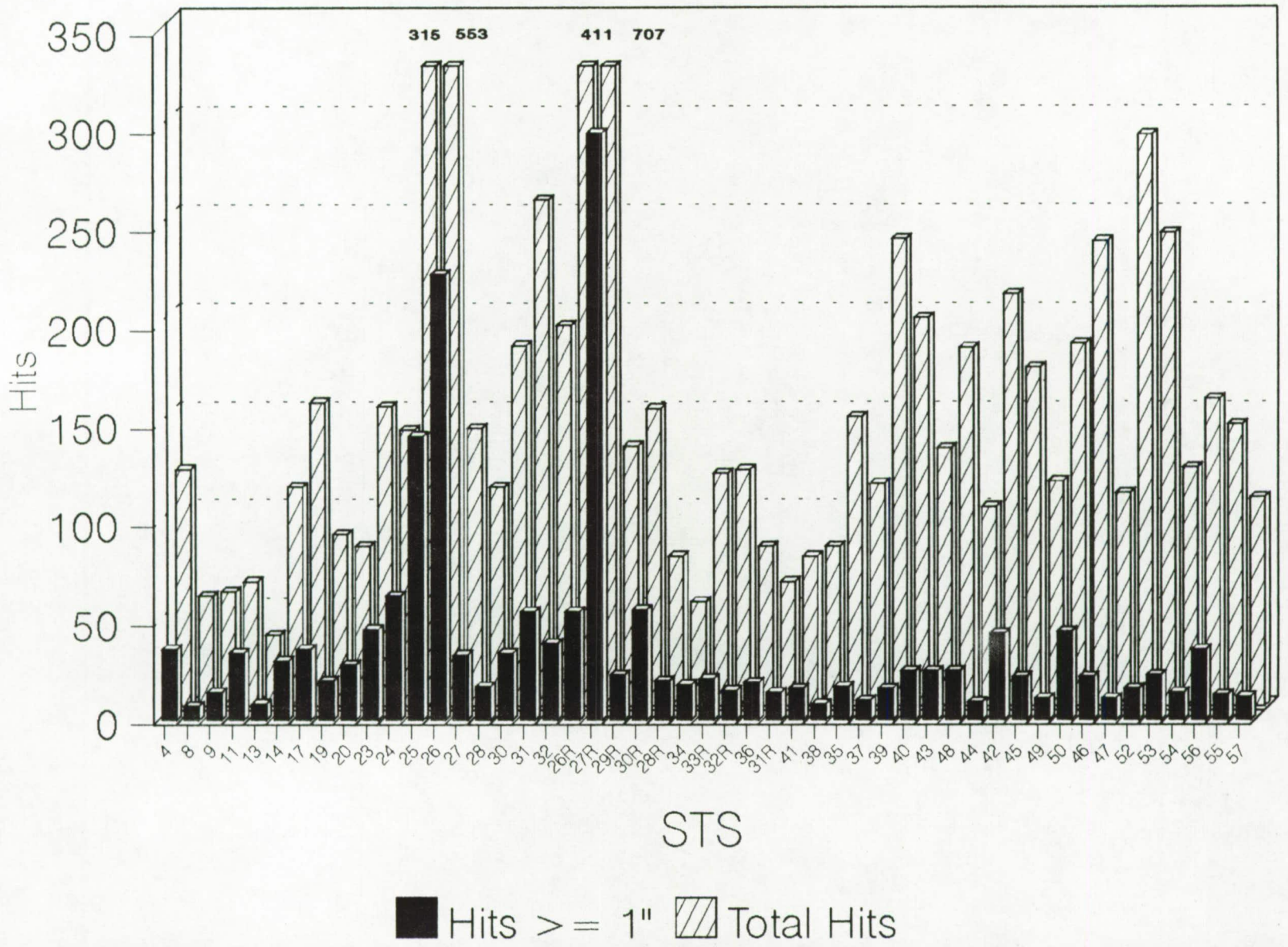
FIGURE 15. *ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY*

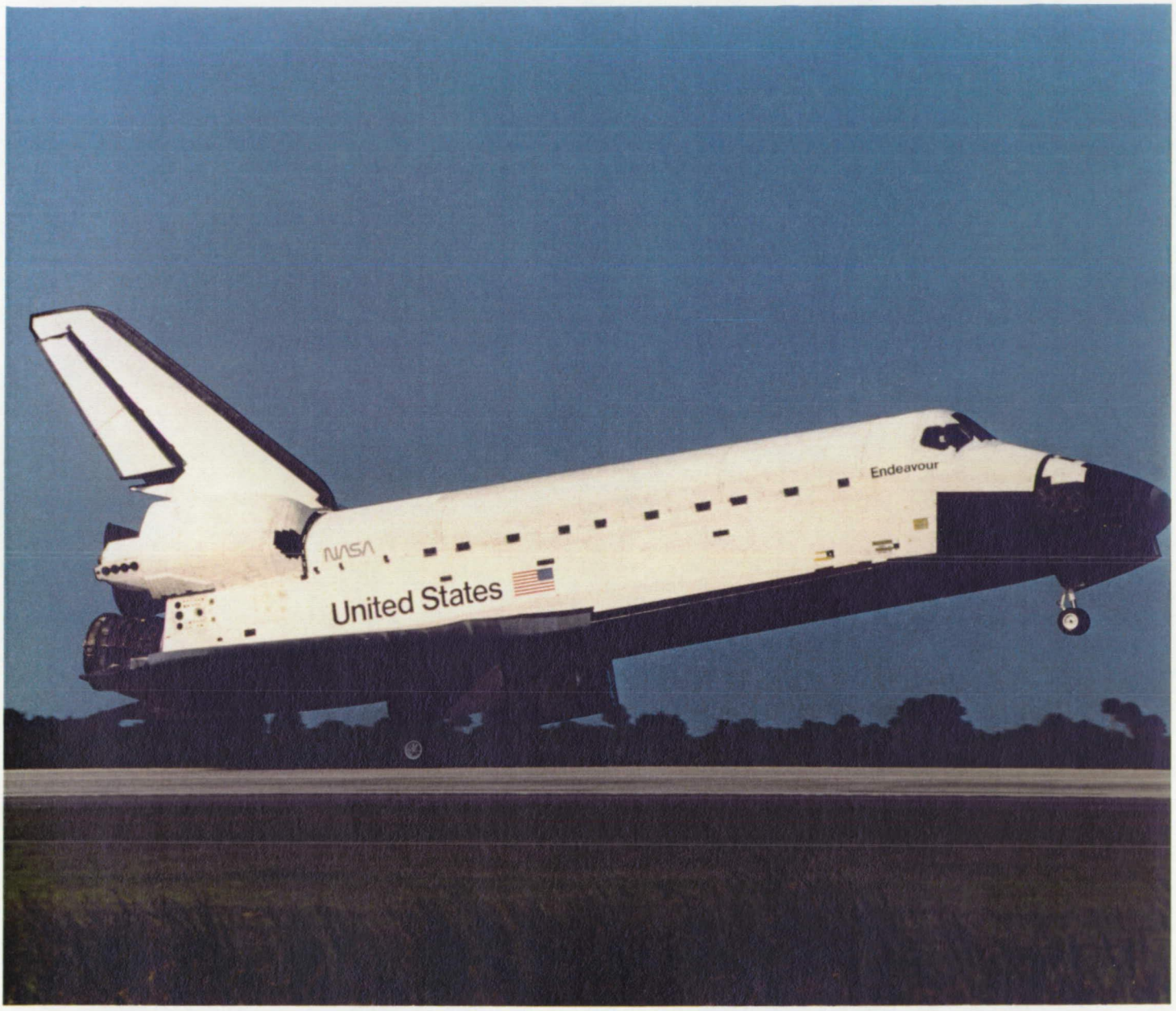
	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
AVERAGE	14.6	94.1	22.1	133.4
SIGMA	7.4	45.7	10.9	61.0
STS-57	10	75	12	106

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

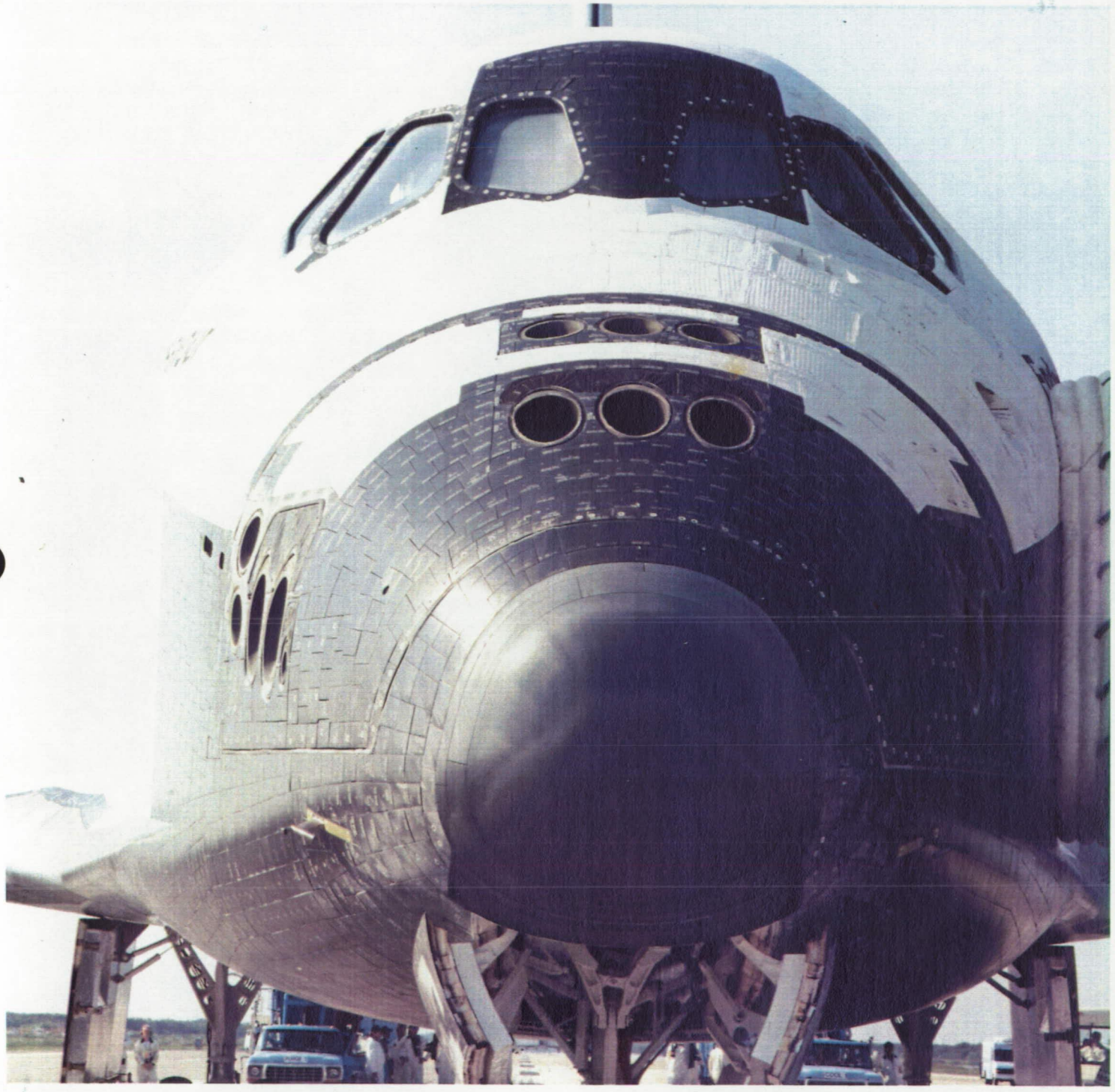
FIGURE 16.

COMPARISON TABLE

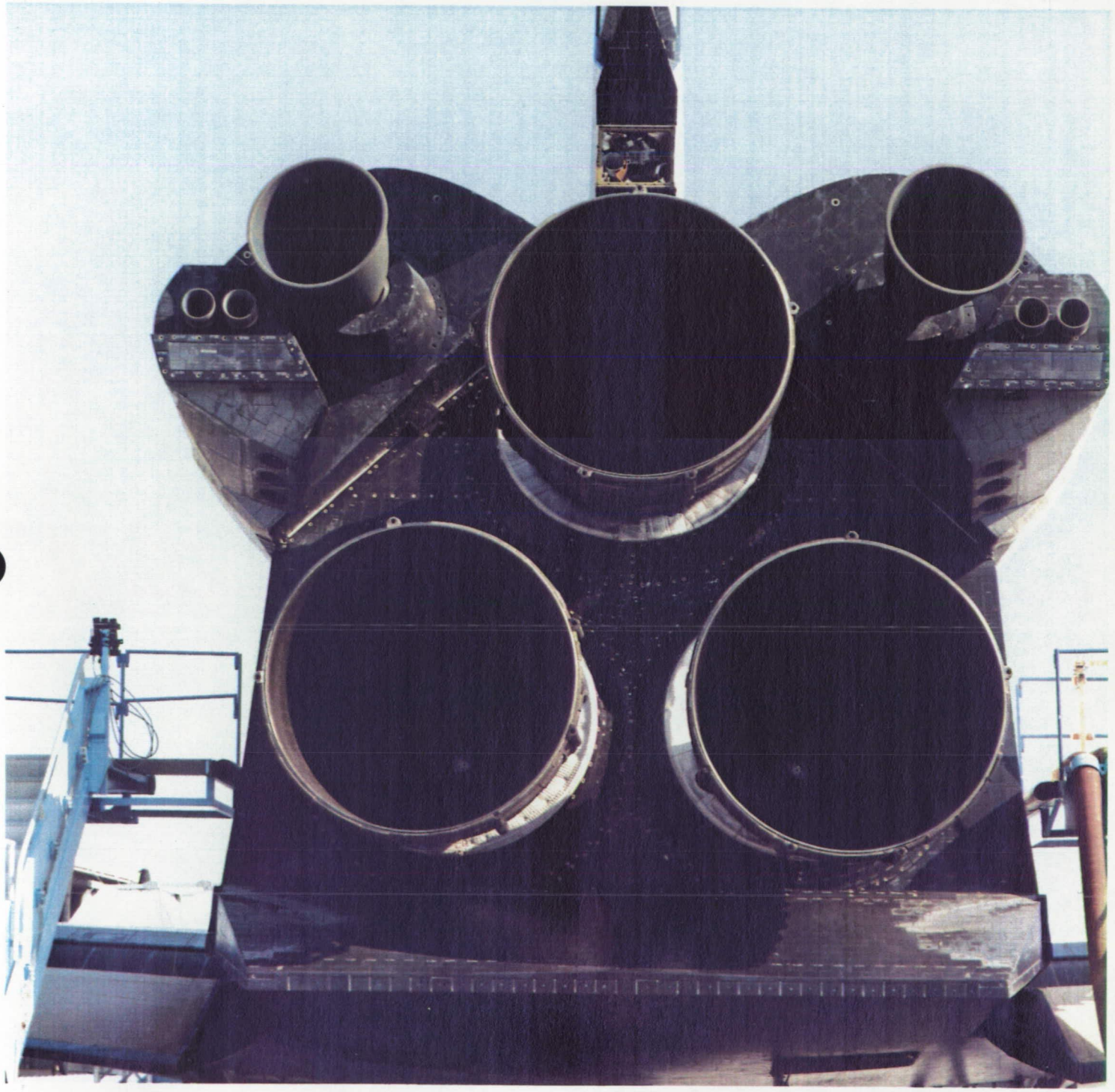




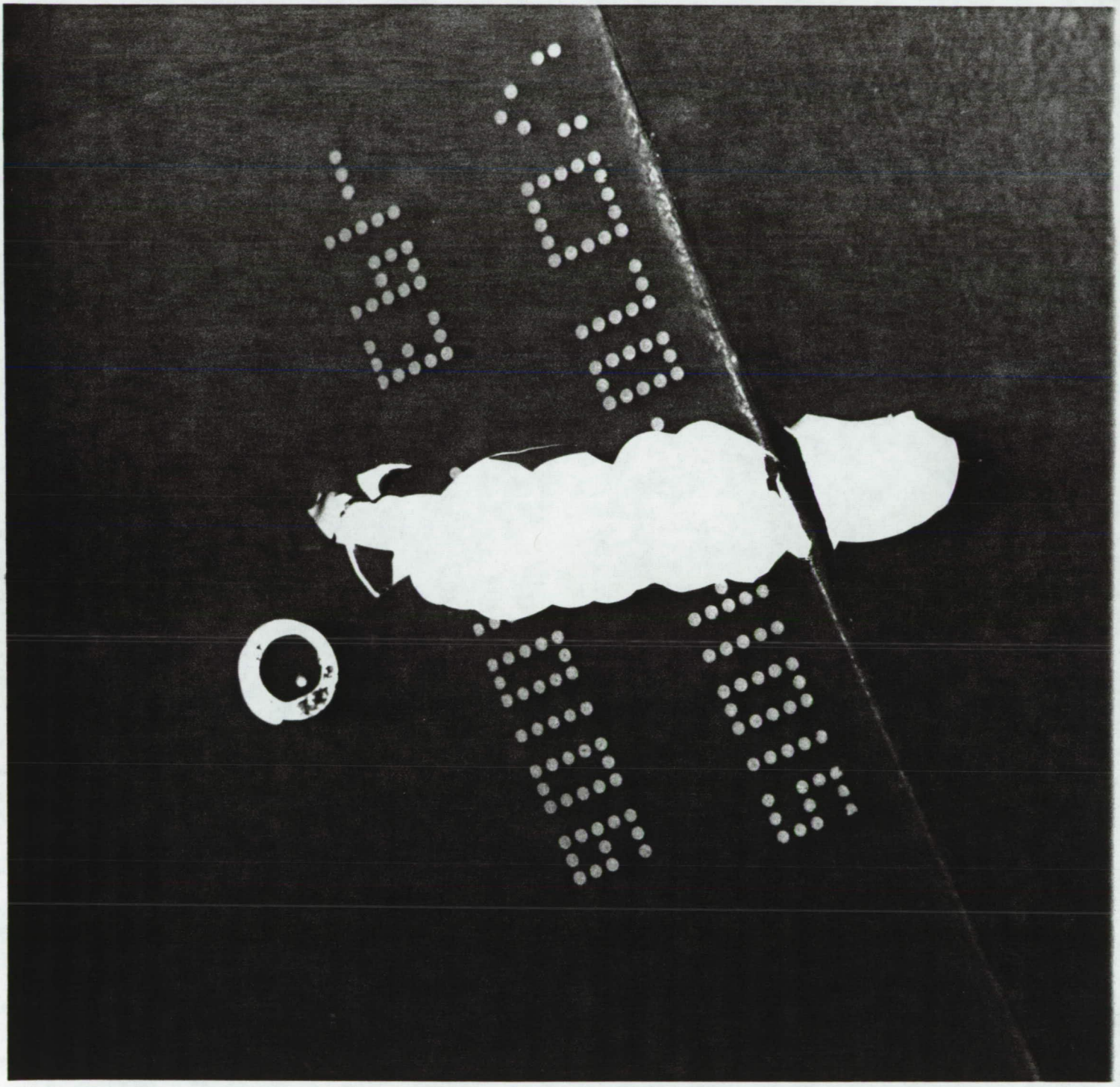
Overall view of OV-105 right side. Endeavour made the 16th KSC landing on Runway 33 on 1 July 1993.



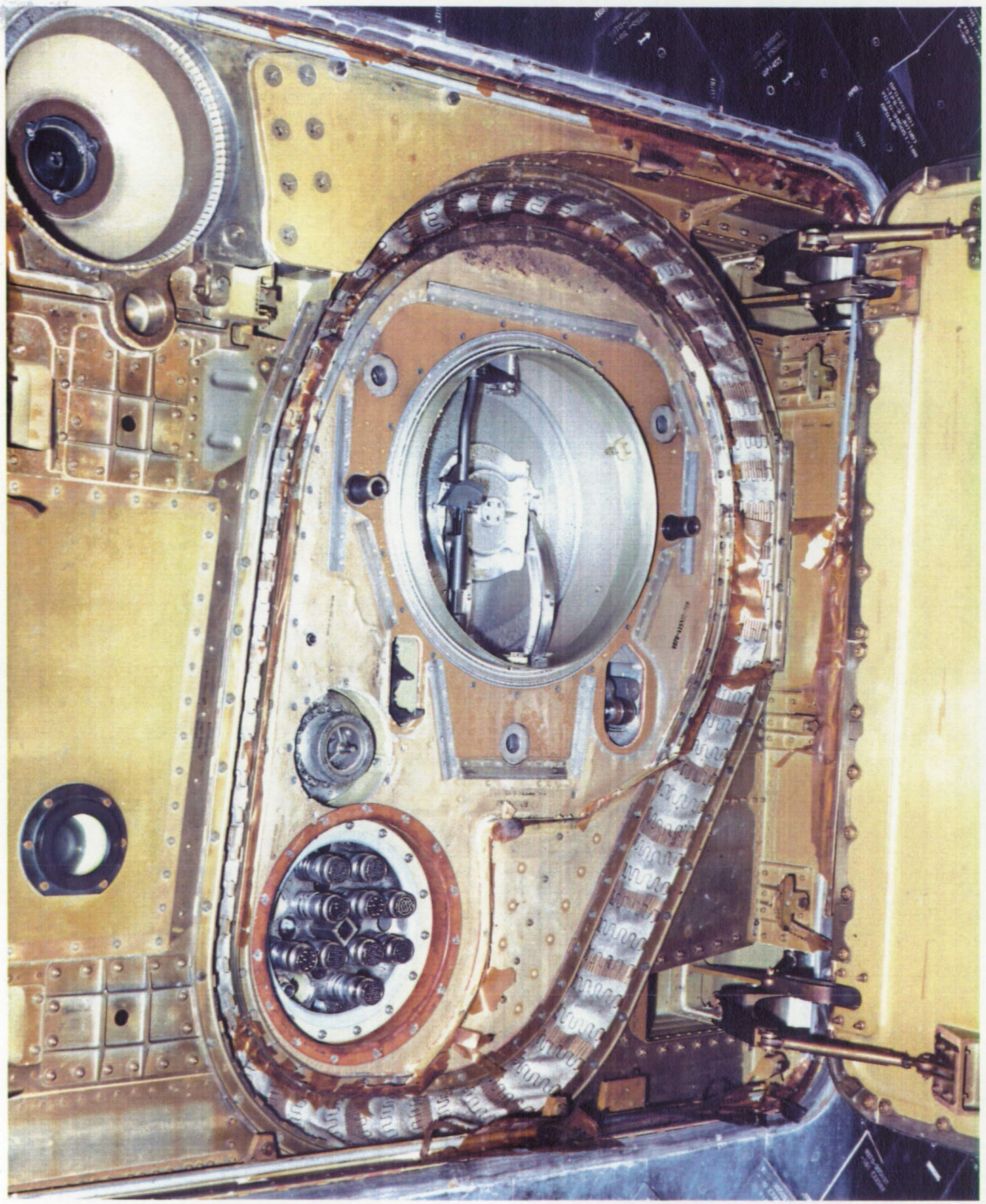
Overall view of the Orbiter nose. Forward facing windows were moderately hazed. Note discoloration of the AFRSI near the F3D and F1F thrusters.



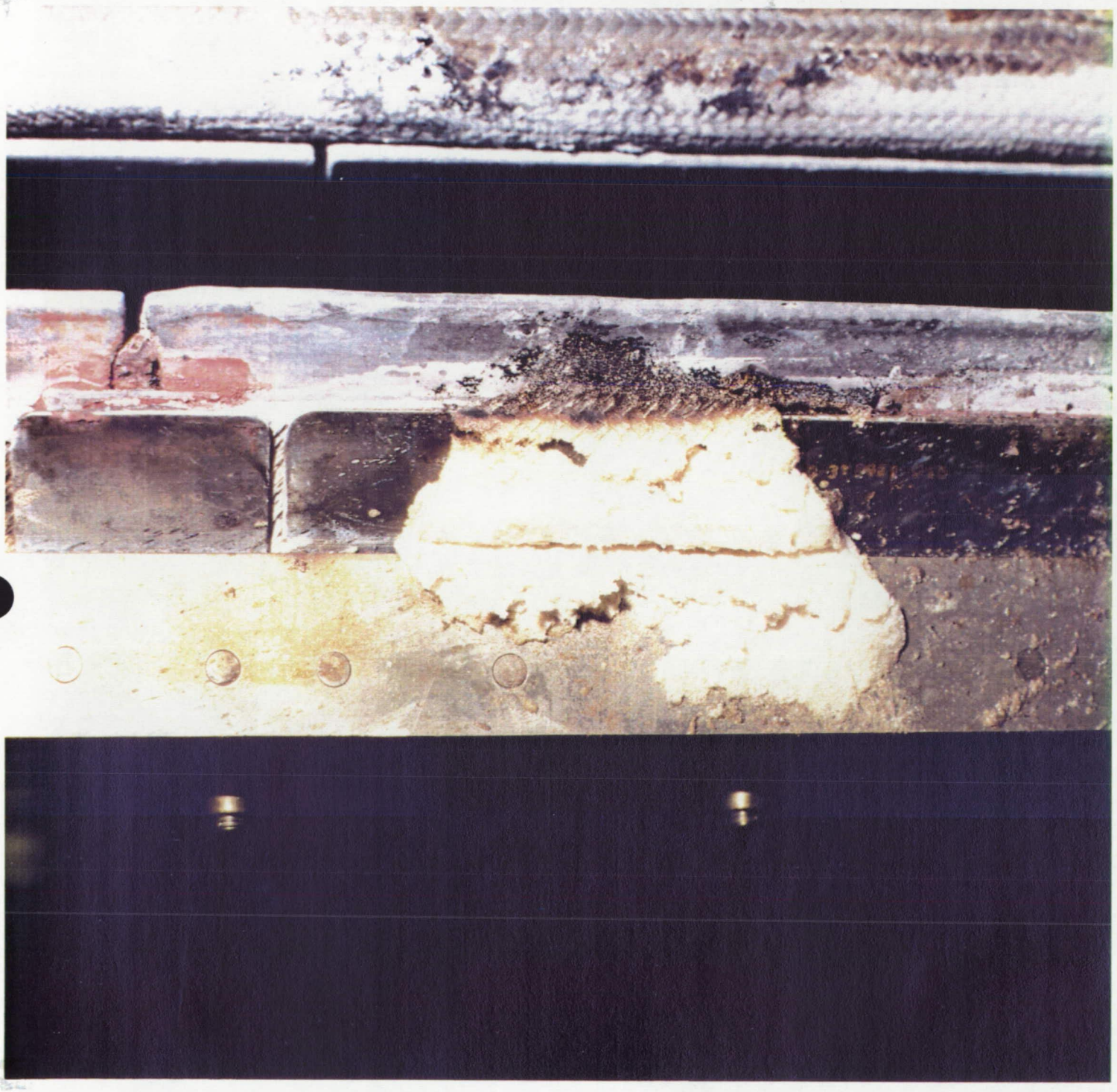
Tile damage on the base heat shield was average. The SSME Dome Mounted Heat Shield (DMHS) closeout blanket sacrificial panels were intact and missing no material.



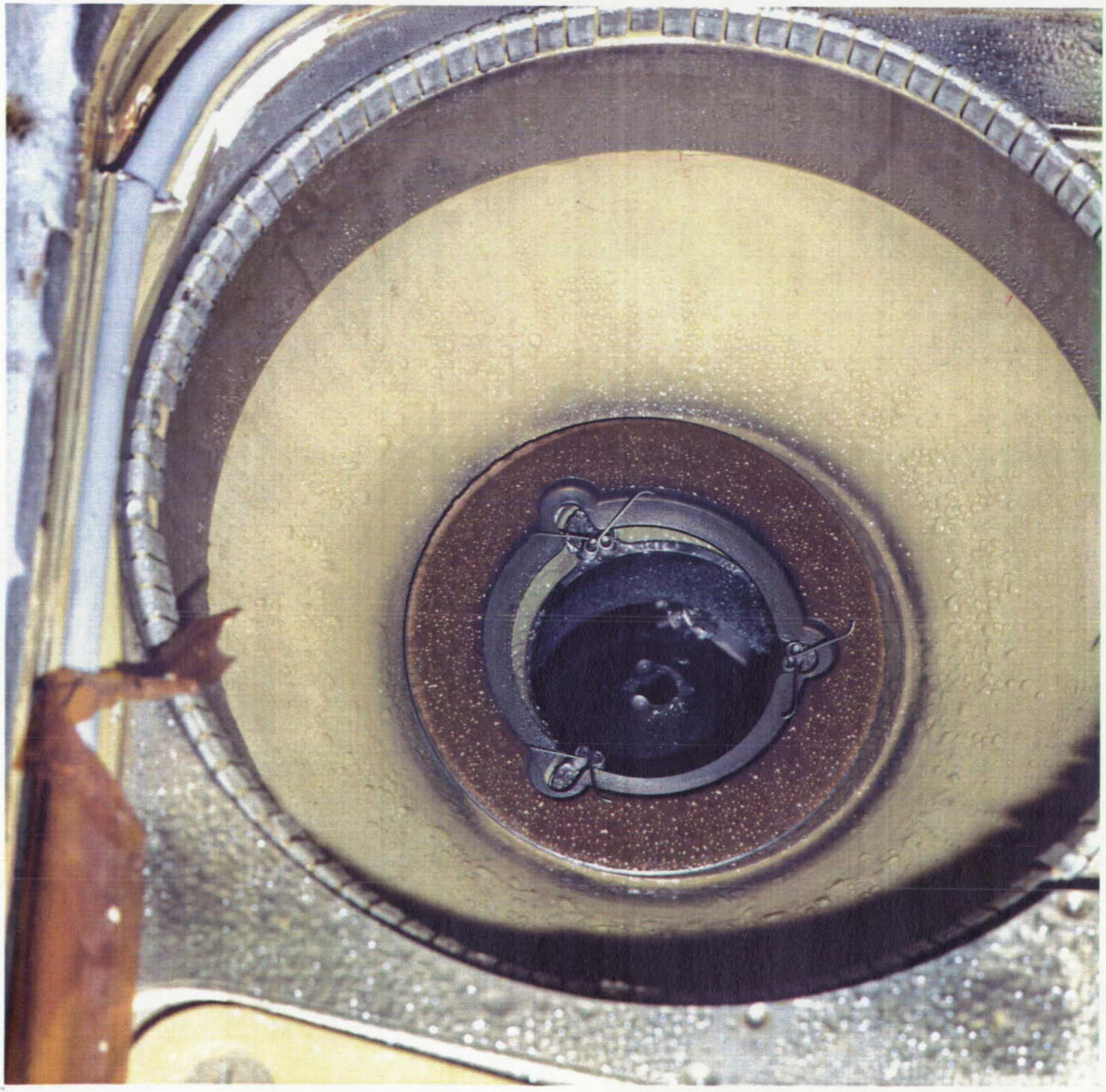
The Orbiter lower surface sustained a total of 75 hits. The largest tile damage site measured 3.5" x 0.75" x 0.375" and was located on the RH lower surface outboard of the nose landing gear door.



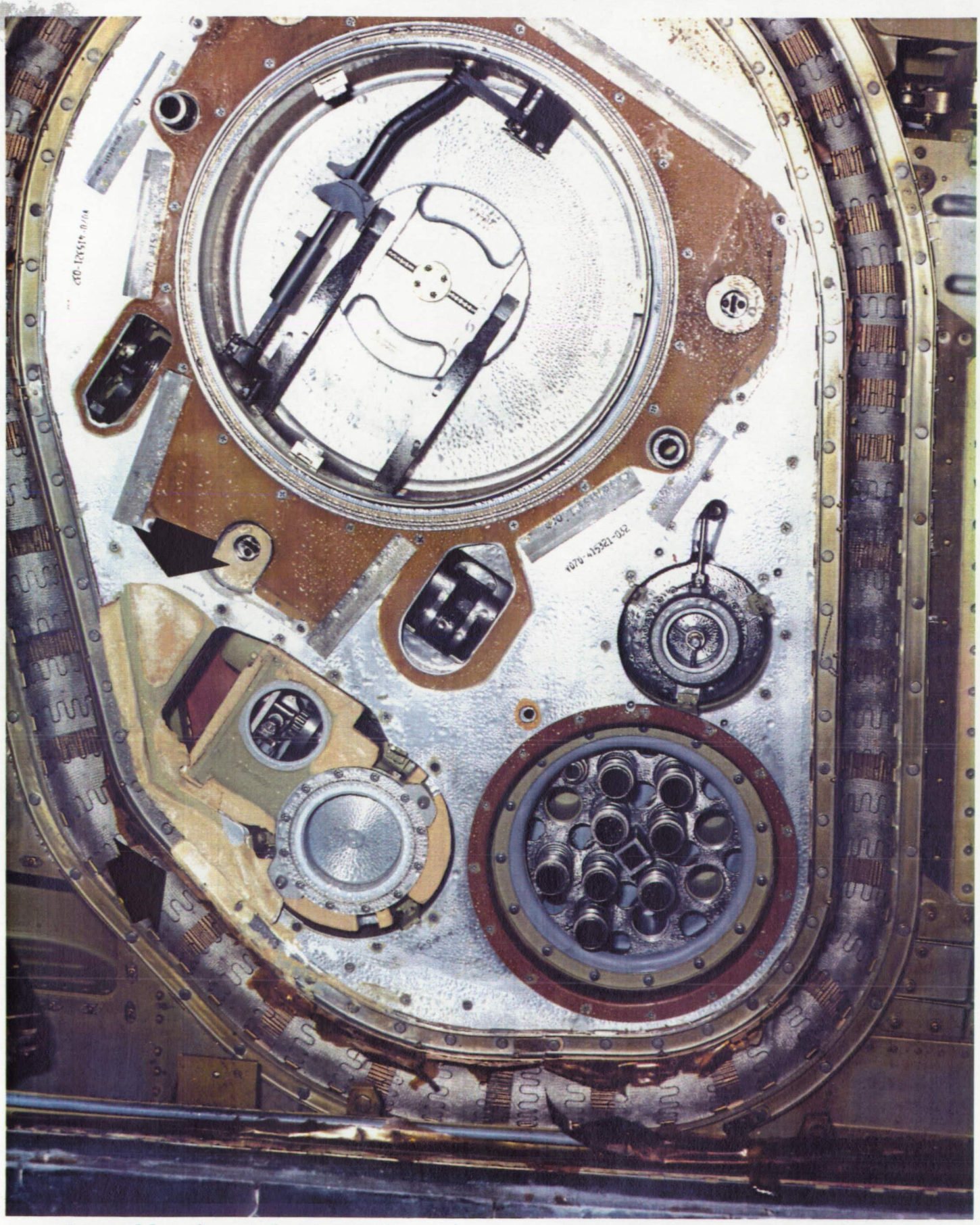
Overall view of the LO2 ET/ORB umbilical. All separation ordnance devices functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.



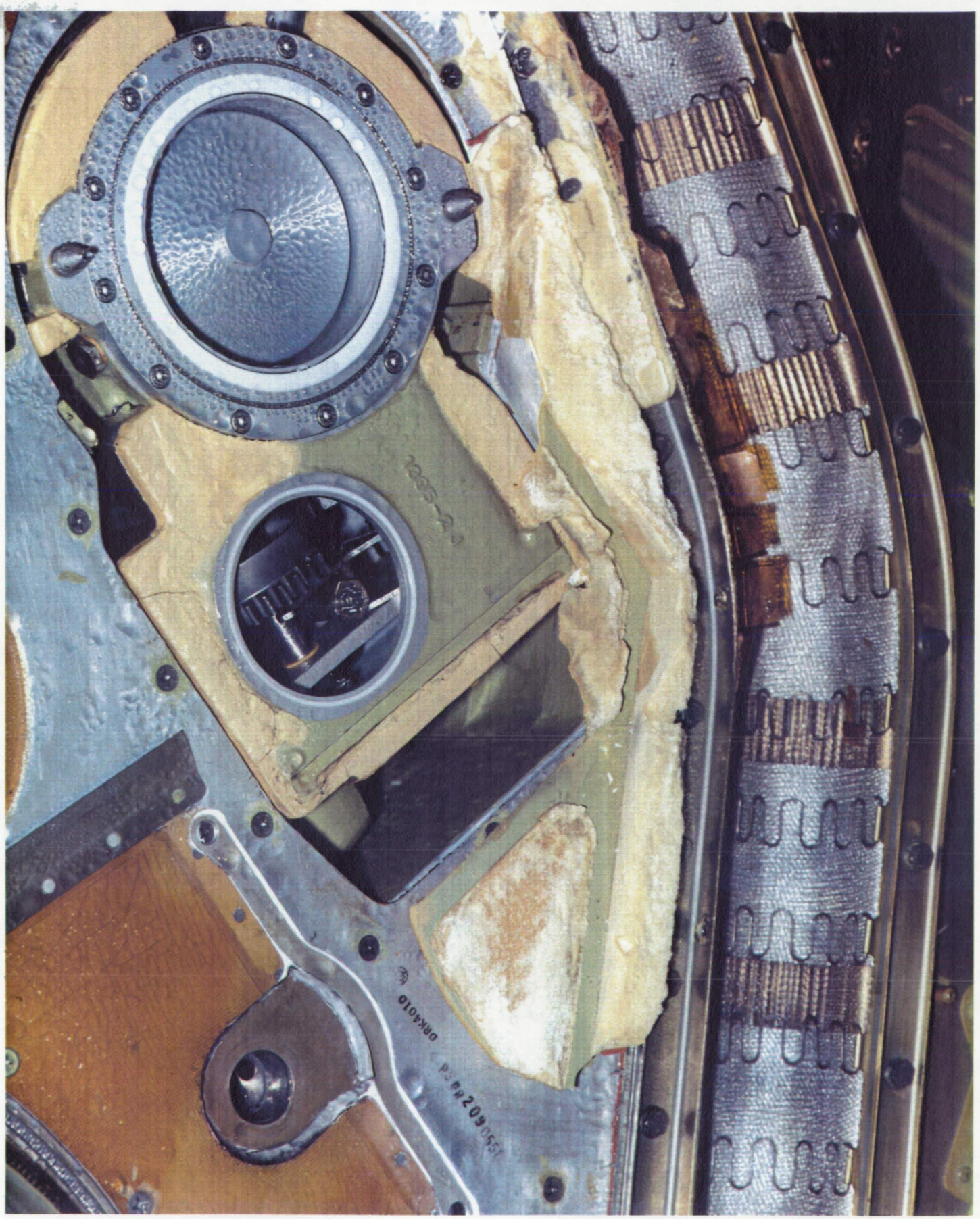
Visual inspection of the right ET door (LO2 side) revealed a 3" x 1" piece of foam adhering to a tile near the hinge line. The foam had been compressed into the thermal barrier when the door was closed, but apparently did not affect the seal.



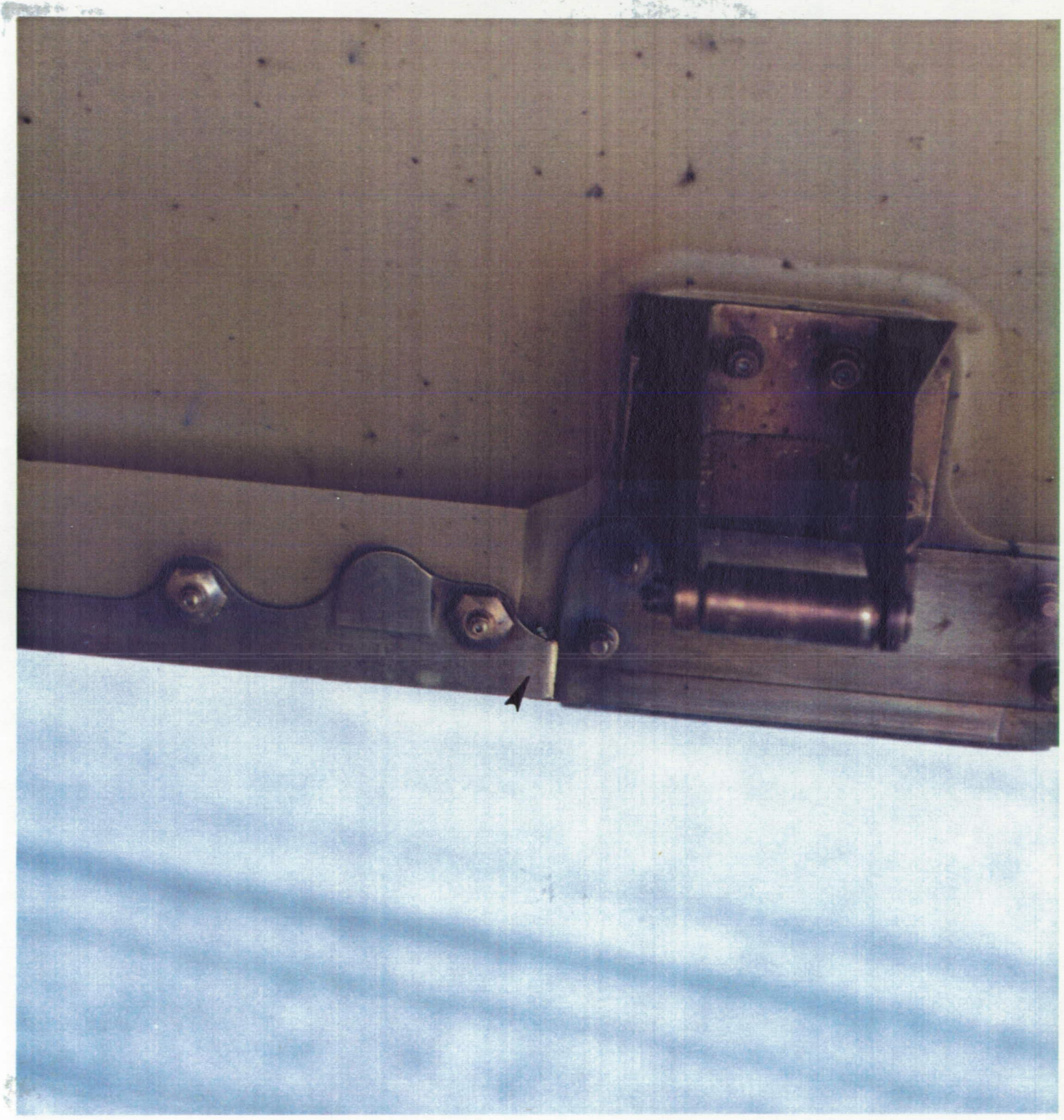
The left ET/ORB attach point (EO-2) hole plugger had not seated and was obstructed by ordnance fragments



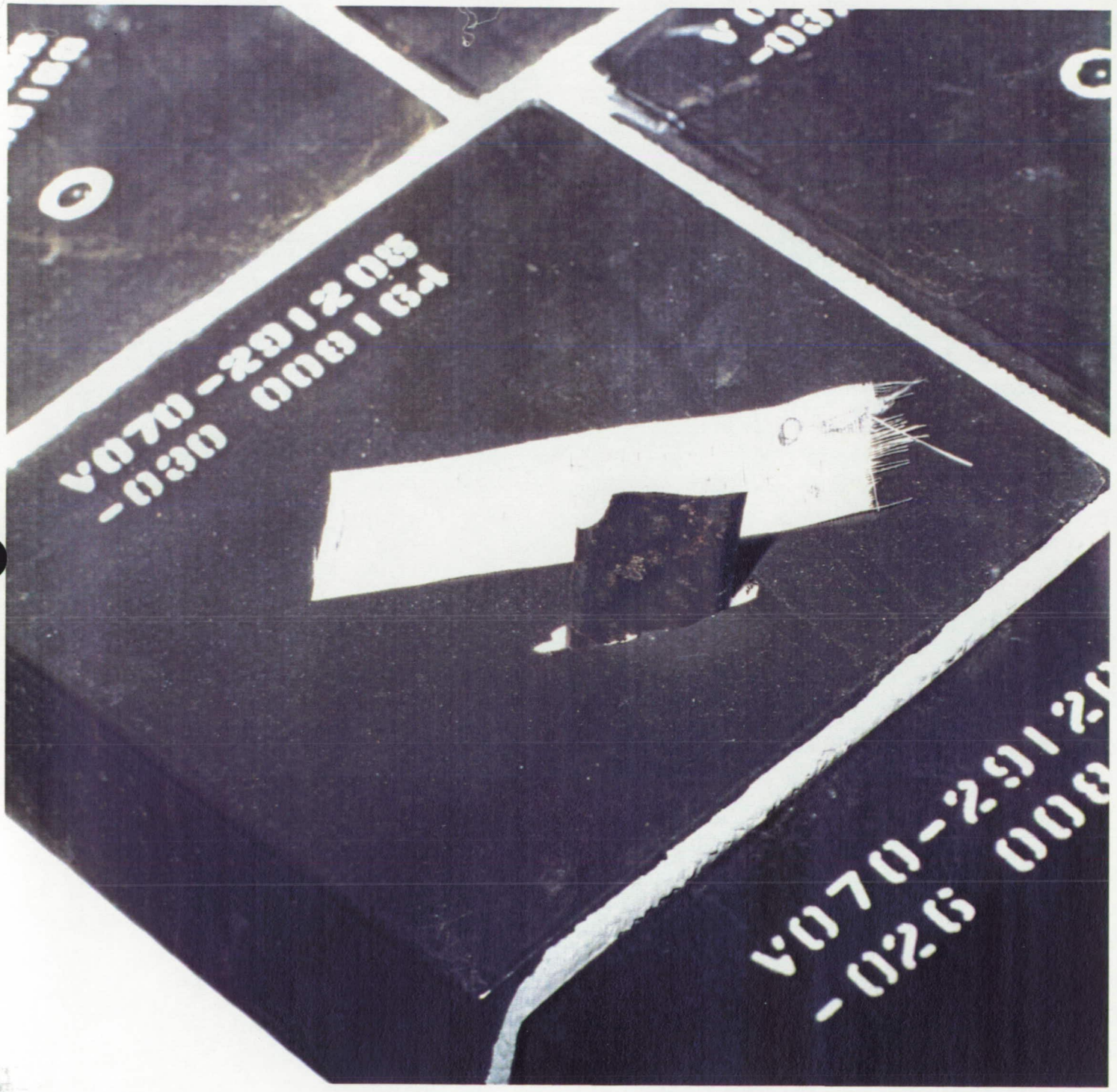
Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices functioned properly. Note piece of umbilical foam adhering to the plate adjacent to the 4-inch disconnect.



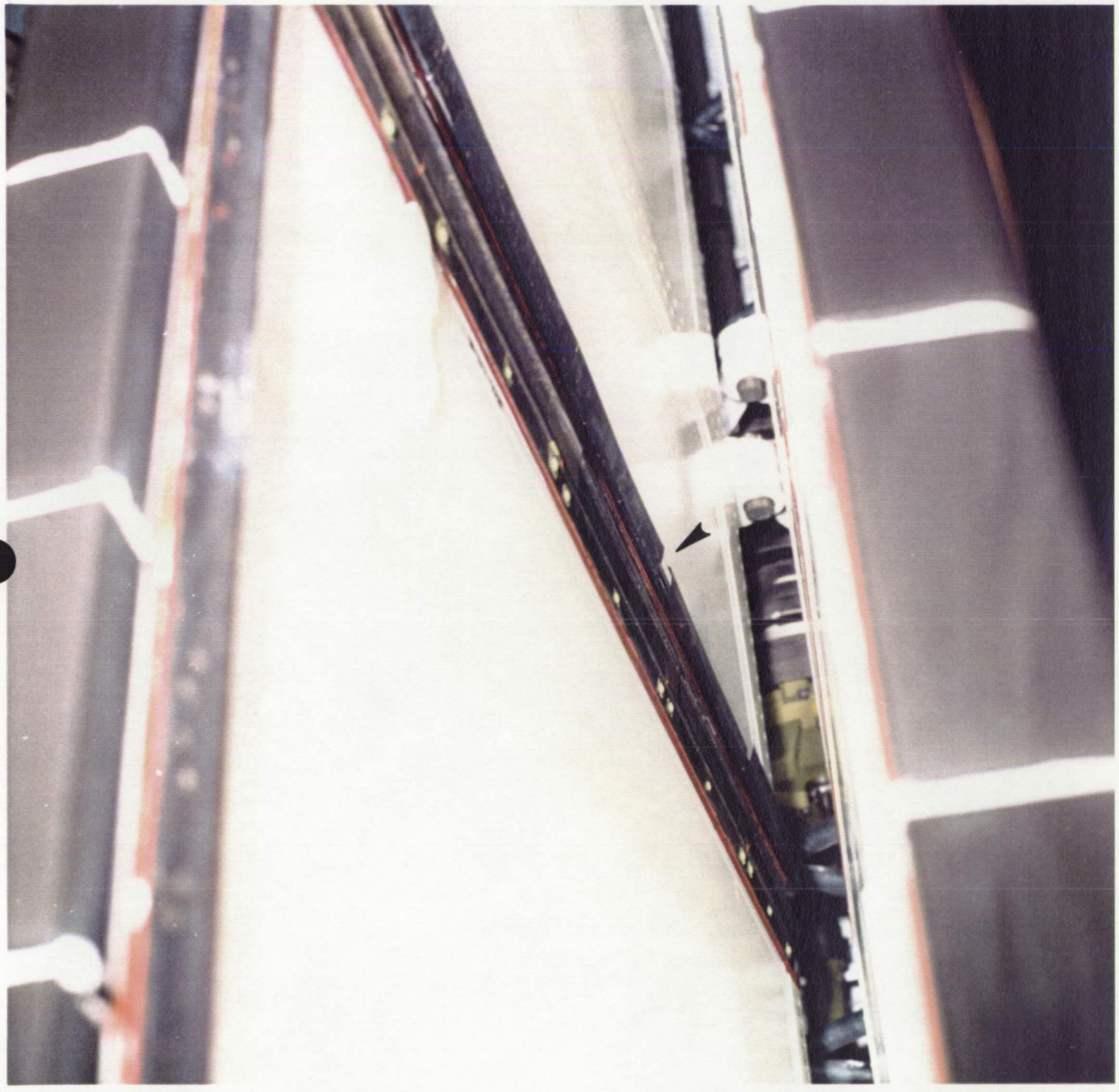
A 15-inch long piece of foam with red purge seal, which should have remained with the ET during separation, adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve.



A small screw from the purge barrier retainer was found on the runway below the LH2 ET/ORB umbilical cavity. A nutplate with threads matching the screw, shown here, was wedged in a cavity on the left ET door.



A 2" x 1" piece of metal spring was embedded in a tile on the vertical stabilizer stinger near the hinge



The piece of metal spring originated from the inside surface of the rudder/speed brake left panel

9.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-105 Endeavour during the STS-57 post landing debris assessment at the Kennedy Space Center. The submitted samples consisted of 8 window wipes (Windows 1-8). The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves the placing and correlating of particles/residues with respect to composition, thermal (mission) effects, and availability. The debris sample result summaries are given by Orbiter location in the following paragraphs and shown in tabular form in Figure 17.

Orbiter Windows

Samples from the Orbiter windows indicated exposure to SRB BSM exhaust (metallics, aluminum and ferrous corrosion), Orbiter Thermal Protection System (RTV, tile, insulation, tile filler), paints and primer from various sources, landing site products (alpha-quartz, calcite), window polish residue, and organic materials. A finding that has been previously observed (STS-50 vertical stabilizer sample, STS-56 and STS-55 window samples) was the presence of "E-glass". Trace amounts of yellow paint were found in all of the 8 window samples and was attributed to facility/ground support equipment paint. Final results of the organic material analysis are still pending. There was no apparent vehicle damage related to any residual finding.

STS-55 Organic Analysis

The final results of the STS-55 organic analysis are also shown in this report. Types of identified materials included those associated with window covers (plastic polymers, foam/adhesive, rubber), RTV, and cellulosic (sample cloth). This variety of residuals, which were attributed to known sources, did not change significantly when compared to previous sample data (reference Figure 17). No new findings were found in this analysis.

New Findings

This sampling set provided two new findings in debris residual post-flight samples. These new findings were obtained from the window samples and did not appear related to any debris damage problem. A building type of insulation and a possible teflon particle were detected. Additional testing is continuing to identify and isolate the source for these findings.

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

Figure 17. Post Landing Orbiter Microchemical Sample Results

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

Figure 17. Post Landing Orbiter Microchemical Sample Results

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

Figure 17. Post Landing Orbiter Microchamical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
35	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Organics	RTV, Tile (ORB TPS) Metallic - Rust, Aluminum Welding Slag (Facility)		
38		RTV, Tile (ORB TPS) Hypalon Paint (SRB) Ensolite Foam (RCC Prot. Cover)	Tile (ORB TPS)		
41	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Tile (ORB TPS) Salt (Landing Site)	Tile (ORB TPS)	Calcite (Landing Site) Fluorocarbon (Viton-ORB Umb) Foam (ORB C/O)	Fwd FRSI - Silicon Mat'l (ORB TPS)
31R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Foam Insulation (ET/SRB) Paint	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Paint		
36	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Salt (Landing Site) Paint	Rust - BSM Residue (SRB) Tile (ORB TPS) Paint Organics	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Microballoon (ET/SRB)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Microballoon (ET/SRB) Calcite (Landing Site) Foam, Organics (ORB Umb C/O)	
32R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) Tile (ORB TPS) Carbon Fibers Titanium	Metallics - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Quartz, Calcite (Landing Site) Organics	
33R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Micaceous Mat'l, Salt (Landing Site) Window Polish Residue (ORB) Paint	Metallics - BSM Residue (SRB) Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Spar, Salt (Landing Site) Organics	RTV, Tile (ORB TPS)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Paint Organics	Crew Hatch Window - Rust - BSM Residue (SRB) - Alpha Quartz (TPS/Landing Site) - Paint - Organics

Figure 17. Post Landing Orbiter Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
34	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Alpha-Quartz, Silicates, Salt (L/S) Window Polish Residue (ORB)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Paint	RTV, Tile (ORB TPS) Stainless Steel Washer	RTV (ORB) Foam (ORB) Viton Rubber (ORB) Metallics - BSM Residue (SRB) Phenolic Microballoon (ET/SRB) Silicates, Calcium (Landing Site) Paint	
28R	Silicone (ORB FRCS Cover Adhesive)	Silicates (Landing Site) Paint Charred Silicone Brass Chip	RTV, Tile (ORB TPS) Clay, Sand, Quartz (Landing Site) Metallics - BSM Residue (SRB)	Sand, Silicates (Landing Site) Foam (ORB) RTV (ORB TPS) Koropon, Kapton (ORB) Metallics - BSM Residue (SRB)	OMS Pod - PVC Laminate (ORB TPS 'Shim')
30R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Clay, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Gap Filler (ORB TPS) Clay, Feldspar (Landing Site)		Upper Tile - Tile,Gap Filler (ORB TPS)
29R	RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Ablator, Hypalon Paint (SRB)		Tile (ORB TPS) Insulation Glass (ORB TPS) Paint Muscovite - Metallics (Landing Site)	Tile (ORB TPS) Umbilical Foam (ORB) Paint Ablator, Hypalon Paint (SRB) Metallics - BSM Residue (SRB)	Upper Tile - Tile (ORB TPS)
27R	RTV, Tile (ORB TPS)	Hypalon Paint (SRB)	RTV, Tile (ORB TPS) Ablator, Hypalon Paint (SRB)		OMS Pod - Iron Fiber - PDL Foam, FRL Paint (ET) - Ablator, Hypalon Paint (SRB)
26R			RTV, Tile (ORB TPS) Paint Rust		

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

Figure 17. Post Landing Orbiter Microchemical Sample Results

10.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 17 post launch anomalies, including six IFA candidates, were observed on the STS-57 mission.

10.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. Three metal items (1-3/8" x 1/4" bolt, 5/8" x 1/4" bolt, 7/8" diameter washer) lay on the MLP deck near HDP #8 between the sound suppression water pipe and SRB exhaust hole.

2. The cable attached to the J2 electrical connector on the GUCP appeared to have excessive slack, which caused the cable to momentarily catch on a intertank access platform hand rail during retraction.

10.2 EXTERNAL TANK

1. At least 70 small divots, 3-4 inches in diameter, occurred on intertank stringers forward of the bipods. Seven small divots were visible in the LH2 tank-to-intertank flange closeout between the bipods.

2. Nine divots, 6-8 inches in diameter, occurred along a line on the -Y thrust panel on the +Z side of the EB fitting. As many as nine smaller divots were scattered on the -Y thrust panel on the -Z side of the EB fitting (IFA candidate).

3. A divot, 6-8 inches in diameter, was present in the -Y (LH) longeron closeout.

4. Foam was missing from the +Y thrust strut flange and primer/ metal substrate was exposed.

5. The lightning contact strip was missing from the top of the LO2 ET/ORB umbilical (IFA candidate).

6. Red purge seal was missing from the LH2 ET/ORB umbilical near the 4-inch disconnect (still attached to the Orbiter after landing) and at the top outboard section. A piece of white RTV drifting by the camera lens may also have originated from the top outboard section. TPS damage had occurred on the inboard side of the umbilical and a large piece of foam, which measured approximately 2 feet long by 4 inches wide by as much as 1 inch thick, had partially separated from the umbilical. TPS on the top surface of the umbilical had peeled back in two places. (IFA candidate).

10.3 SOLID ROCKET BOOSTERS

1. A frangible nut web, 2-1/4" x 5/16", was found on the stud in holddown post (HDP) #2. (The loss of two frangible nut pieces from the stud hole was observed in the film review).

2. The RH frustum had 46 MSA-2 debonds over fasteners and 2 areas of missing MSA-2. The LH frustum had 27 debonds over fasteners.

3. Paint was missing and metal substrate was exposed in several areas of the RH SRM forward segment and LH aft center segment cases.

4. Approximately 10 percent of the EPON shim material on both HDP #7 and #8 aft skirt support structure was missing prior to splashdown. The substrates were sooted/charred.

10.4 ORBITER

1. The EO-2 (LH2 side) debris plunger was obstructed by ordnance fragments.

2. A 15-inch long piece of foam with red purge seal, which should have remained with the ET during separation, adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve. (IFA candidate)

3. A piece of foam 3-inches long adhered to a tile on the RH ET door near the hingeline. The foam had been compressed into the thermal barrier when the door was closed, but apparently did not affect the seal during re-entry.

4. A 7/16" x 3/32" screw from the purge barrier retainer lay on the runway below the LH2 ET/ORB umbilical cavity. A nutplate with threads matching the screw was found wedged in a cavity on the ET door. (IFA candidate)

5. A 2" x 1" piece of metal spring from the inside left surface of the rudder/speed brake was embedded in a vertical stabilizer stinger tile near the rudder hinge. (IFA candidate)

Appendix A. JSC Photographic Analysis Summary

August 6, 1993

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

Dear Greg,

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-57 Final Report, and was completed August 6, 1993. Publication numbers are LESC-30783 and JSC-25994-57. The actual document can be obtained through the LESC library/333-6594 or Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

Christine Dailey, Project Specialist
Photo/TV Analysis Project

2.1 Debris

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 Umbilical Disconnect Debris

(Cameras E-2, E-17, E-18, E-19, E-20, E-25, E-34, E-35, E-36, E-62, E-63, E-76, E-77, OTV-149, OTV-150, OTV-151, OTV-170, OTV-171)

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

2.1.1.2 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris

(Cameras E-1, E-4, E-5, E-6, E-15, E-16, E-17, E-18, E-25, E-30, E-31, E-40, E-52, OTV-109, OTV-154, OTV-163)

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

2.1.2 Debris Near the Time of SRB Ignition

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

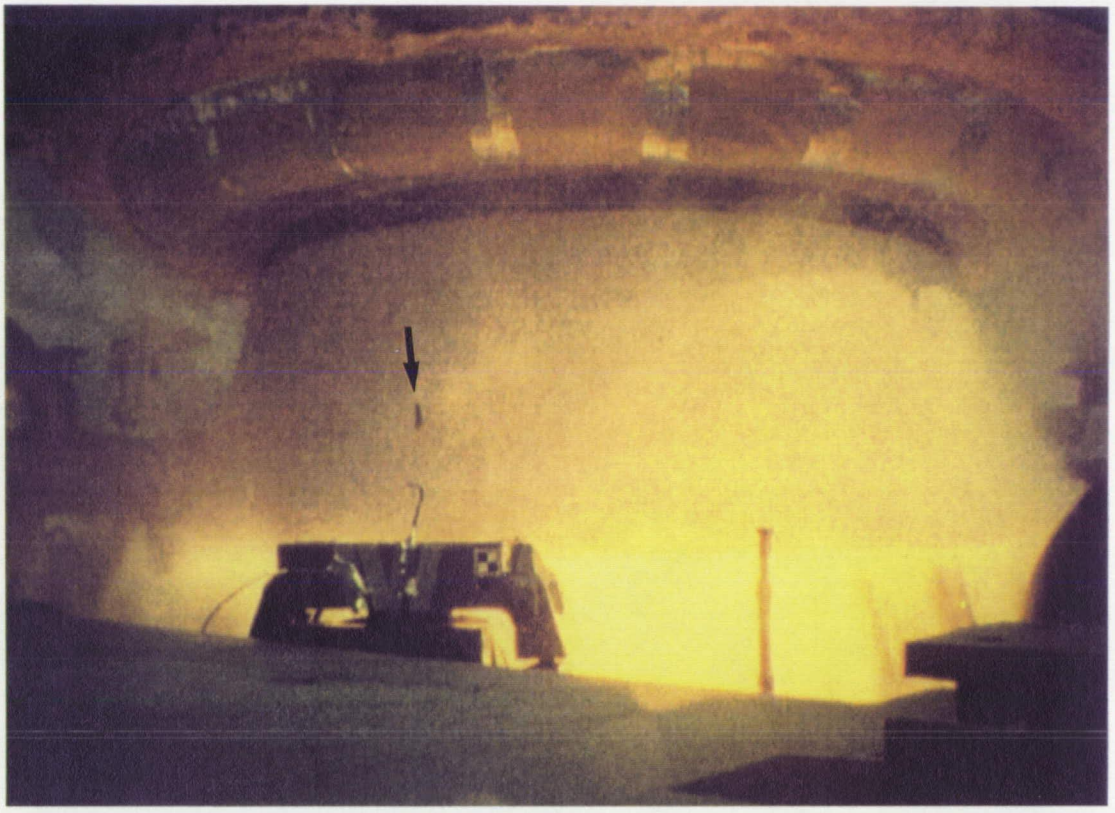


Figure 2.1.2.1 Metallic Debris from DCS Stud Hole of the RSRB HDP M-2

A metallic appearing piece of debris (see Figure 2.1.2.1) was noted to fall from the DCS stud hole of the RSRB holddown post M-2 at liftoff (13:07:23.048 UTC).

2.1.2.2 Debris near SRB HDPs at SRB Ignition
(Cameras E-7, E-8, E-11, E-13)

A small dark piece of debris came from behind the holddown post M-4 DCS and another dark piece of debris came from behind the east side of the LSRB holddown post M-6 DCS at liftoff (13:02:22.000 UTC). Another single small dark piece of debris was noted near LSRB holddown post M-7 DCS area. The debris possibly originated from the DCS area. None of the DCS debris described appeared to strike the vehicle.

A small flat dark piece of debris appeared to move toward and contact the outer surface of the RSRB support structure (foot) of holddown post M-2 (13:07:18.959 UTC). No damage was visible from the contact.

2.1.2.3 SRB Flame Duct Debris *(Task #7)* *(Cameras E-8, E-11, E-12, E-15, E-26)*

As on previous missions, several pieces of debris were noted originating from the Solid Rocket Booster (SRB) flame duct area after SRB ignition. The SRB flame duct debris seen on STS-57 was not significant and required no analysis.

2.1.2.4 MLP Debris Near LSRB at Liftoff *(Camera E-26)*

A small dark piece of debris (possibly SRB flame duct debris) was noted traveling south between the LSRB and the FSS at 13:07:22.623 UTC. The debris was first seen to the north of the SLV and traveled in an arch towards the Orbiter. The debris was not noted in any other cameras to allow a phototheodolite analysis of the trajectory and velocity, but did not appear to be in the vicinity of the Orbiter when the debris exited the field of view. No further analysis was completed.

2.1.2.5 Debris Near LO2 Feedline
(Cameras E-65, E-79)

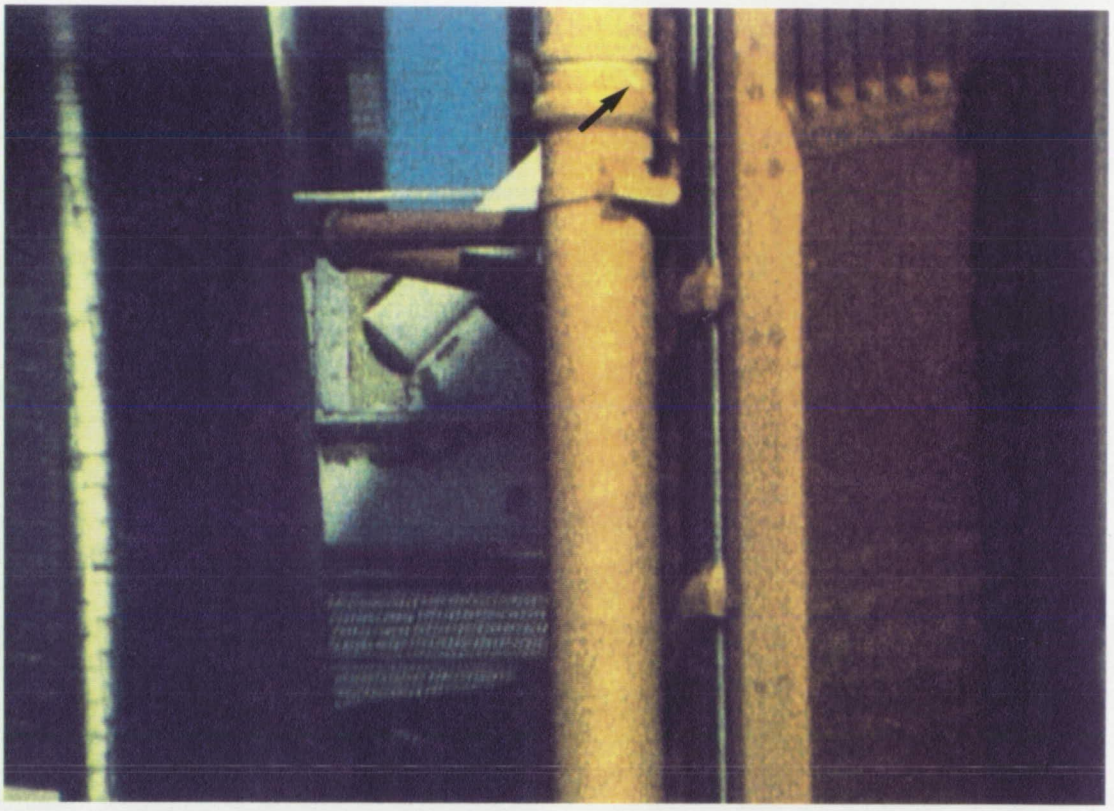


Figure 2.1.2.5 Debris from LO2 Feedline Joint

A white piece of debris (probably ice, approximately 3 inches in length) appeared to originate from the joint on the LO2 feedline near the forward bipod (see Figure 2.1.2.4) and fall along the LO2 feedline during liftoff on camera E-65. A smaller piece of debris was seen falling along the LO2 feedline at a lower location during liftoff on camera E-79. Neither debris item was seen to contact the vehicle.

2.1.2.6 Debris Falls along North Side of ET
(Camera E-4)

Two small white pieces of debris were noted falling along the north side of the ET (the side opposite of the Orbiter) at liftoff. These debris pieces might have originated from the GUCP area.

2.1.3 Debris after Liftoff

2.1.3.1 RCS Paper and Baggie Material Debris
(Cameras E-34, E-35, E-40, E-52, E-54, E-59, E-65, E-207, E-212, E-218, E-222, E-223, E-224, OTV-149, OTV-161, OTV-170, KTV-21B)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) at liftoff, throughout the roll maneuver, and beyond on the launch tracking views. Most of the debris sightings were probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. On the E-223 tracking camera view, RCS paper debris was seen to originate from the F2R and F4R RCS nozzles. None of the debris detected after liftoff was observed to strike the vehicle. No follow-up action has been requested.

2.1.3.2 Debris Near Left Wing at 15.6 Seconds MET
(Cameras E-52, E-222, KTV-21B)

A light colored piece of debris fell along the body flap and aft into the SSME plume at approximately 15.6 seconds MET (13:07:37.576 UTC). This does not appear to be RCS paper debris. The debris was first noted near the inboard aft trailing edge of the left wing on the camera E-222 film. The debris was first seen near the LH2 TSM disconnect area on camera E-52.

2.1.3.3 Multiple Pieces of Debris at 17 Seconds MET
(Camera E-59)

Multiple pieces of small light colored debris were noted on the ET side of the RSRB plume at approximately 17 seconds MET (13:07:39.244 UTC).

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

Shortly after launch, the crew was asked to give a report of any debris they noted during launch and ascent. Commander Ronald Grabe reported that the windows were clean. He also reported that detection of debris was made difficult by the sun position relative to the Orbiter.

2.2 MLP Events

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen)
(Cameras E-2, E-19, E-20, OTV-163, OTV-170, OTV-171)

Orange vapor, possibly free burning hydrogen, was noted below the SSMEs near the left OMS nozzle and also north of the body flap at SSME ignition. Orange vapor was noted above the SSME #1 nozzle at 13:07:18.429 UTC on camera E-2. This phenomenon has been noted on many previous missions.

2.2.2 Green Vapor Near Left OMS Nozzle
(Camera OTV-171)

A greenish vapor was noted between SSME #1 and SSME #2 near the left OMS nozzle during SSME ignition. This phenomenon has been noted on previous missions.

2.2.3 Flashes in SSME Plumes after SSME Ignition
(Cameras E-2, E-3, E-19, E-20)

Flashes were noted in the SSME #1 exhaust plume at 13:07:19.404 and 13:07:22.571 UTC. A flash was seen in the SSME #2 plume at 13:07:22.359 UTC. A flash was noted in the SSME #3 exhaust plume at 13:07:19.860 UTC. Flashes in SSME exhaust plumes have been seen on prior missions. No follow-up analysis was requested.

2.2.4 Hydrogen Burn Ignitor Flare
(Cameras E-1, E-30, E-76, OTV-170)

A hydrogen burn ignitor flare was noted at SSME startup.

2.2.5 Discoloration in RCS Port Covers
(Cameras E-19, E-20, E-77, OTV-170, OTV-171)

A discoloration of the L2U, L4U, and R4U RCS port covers was noted prior to liftoff.

2.2.6 Slack GH2 Vent Arm Retraction Lanyard
(Cameras E-42, E-50)

During the GH2 vent arm retraction, the lanyard was slack and appeared to contact the hand railing of the FSS.

2.2.7 Firing Cable Remained Attached at HDP #4
(Cameras E-7, E-15)

A portion of the firing cable from holddown post M-4 remained attached to the RSRB after liftoff.

2.3 Ascent Events

2.3.1 White Vapor Near SSME #3
(Cameras E-6, E-31, OTV-109)

A white vapor was noted near the north side of SSME #3 after liftoff on OTV-109. The white vapor off SSME #3 appeared normal on the camera E-6 view.

2.3.2 Light Colored Streak in SSME Plume
(Cameras ET-204, ET-212)

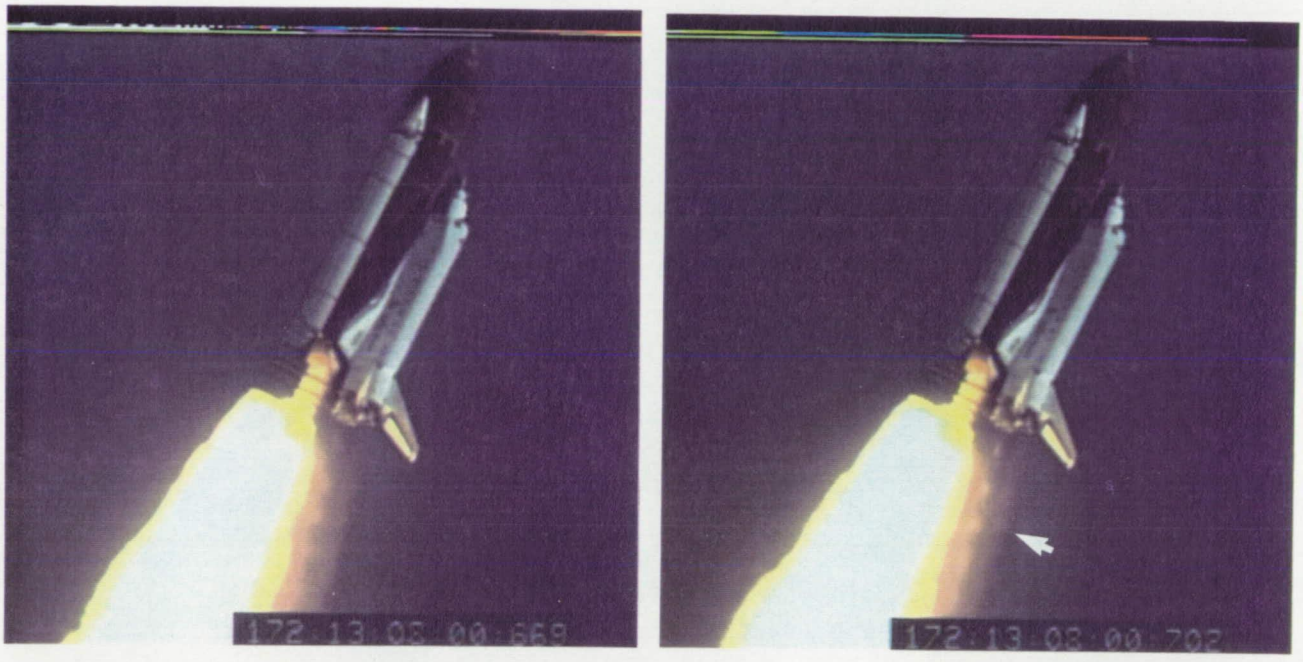


Figure 2.3.2 **Light Colored Streak in SSME plume at 38 seconds MET and Reference Image**

A light colored streak was noted in the SSME plume at approximately 38 seconds MET on ET-212. Figure 2.3.2 provides an image of the streak along with an image of an earlier time without the streak. A white puff (believed to be the same event seen from a different perspective) was noted at the same time and similar position on camera ET-204.

2.3.3 Flares in SSME Exhaust Plume
(Cameras E-207, E-212, E-222)

Multiple flares in the SSME exhaust plume were noted after the roll maneuver. The flares were seen at approximately 27.7, 33, 33.6, 36.2, and 36.3 seconds MET. Flares in the SSME exhaust plume have been seen on previous missions.

2.3.4 Body Flap Motion *(Task #4)*
(Camera E-207)

During ascent very slight body flap motion was noted on the E-207 tracking camera film. The magnitude of the motion seen on the STS-57 views was not sufficient to warrant further analysis.

2.3.5 Condensation Collar *(Task #12)*
(Cameras E-204, E-207, E-208, E-211, E-212, E-220, E-222, E-223, E-224, ET-204, ET-207, ET-208, ET-212, KTV-4B, KTV-5, KTV-13, KTV-21B)

Dick Thomas of RI-D noted while watching the national news coverage of the launch of STS-57 that there may have been excessive vapor clouds around the SLV during ascent and that this vapor might be related to a cause of payload bay door seal damage which has occurred on several flights (e.g. STS-41, STS-40). His concern was for pressure spikes that the payload bay may be experiencing and thought he might have seen an ingestion of air into the payload bay.

STS-57 video trackers were rescreened to see if there was any turbulence of the air around or entering into the payload bay doors at the seal areas. (The condensation occurred between mach 0.87 and mach 1.16.) The condensation collar in these views did not appear turbulent, however it was seen to pulse several times during ascent. (This event has been seen on several previous missions and is due to levels of moisture in the atmosphere that the SLV is traveling through.) There appeared to be no visible influx of air into the payload bay. The collar appeared to be separated from the Orbiter and did not actually touch the payload bay doors except at the forward end of the SLV where the condensation collar begins. The condensation also appeared to originate from the edges of the wings, OMS pods, and the vertical stabilizer. This phenomenon has also been seen on previous missions and does not appear out of the ordinary.

STS-40 video tracking views were also reviewed since this was the mission that had significant payload bay door seal damage. The analysis of these views was hampered due to numerous clouds in the area during ascent. In the areas where the collar was visible, the condensation was comparable to that of STS-57 in amount and shape and did not appear turbulent.

2.3.6 Linear Optical Effect
(Cameras E-212, ET-212)

A linear optical distortion along the aft portion of the SLV was noted at 13:08:15.851 UTC on the ET-212 long range video tracking view. Linear optical effects have been seen on previous mission long range tracking views. No follow up action is planned.

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

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all previous missions. For STS-57, the start of recirculation was observed at about 92 seconds MET on KTV-13 and the end was noted at approximately 115 seconds MET on Camera ET-204. See Appendix D, Task #1 for a summary of recirculation start and stop times for all missions since reflight.

Cameras on which recirculation was observed for STS-57

CAMERA	START (seconds MET)	STOP (seconds MET)
KTV-13	92	107
ET-204	93	115
ET-208	92	107
*E-204	94	109
E-208	~93	~104
E-212	~93	~102

* **BEST VIEW OF RECIRCULATION**

2.3.8 Dark Puffs in SRB Exhaust Plume
(Cameras ET-204, ET-207, E-208)

Dark puffs in the SRB exhaust plume were noted at approximately 114 seconds MET (just prior to plume brightening). This phenomenon has been noted on previous missions.

2.4 DTO-312

2.4.1 Analysis of Onboard Camcorder Downlink of the ET *(Task #11)*

Approximately, three and half minutes of video of the ET was downlinked approximately 8 hours after ET separation. The first video view occurred approximately 9 minutes after ET separation and ended approximately 14 minutes after separation. The video imagery was screened prior to the screening of the handheld or the umbilical well films of the ET separation. A rotational analysis was performed in the same manner that would be performed using the handheld photography. The tank was measured to have a tumble rate of 0.58 degrees per second compared to 2.2 degrees per second as measured from the 35 mm handheld photography. More details of this analysis are located in Appendix D, Task #11. A separation velocity could not be performed because internal camera orientation could not be determined.

The video screening revealed two divots on the -Z axis of the ET, possible divots on the LH2 intertank near the bipod and possible divots on the -Y side of the LH2 intertank interface. The divots noted on the -Z axis were determined to be a single divot after observation of the ET handheld photography. The possible divots noted on the LH2 intertank near the bipod were confirmed by the handheld photography to be multiple divots on the intertank acreage. The possible divots noted on the -Y axis of the LH2 intertank interface were also confirmed by the handheld photography. Although the video did not show all of the damaged areas, it did yield near real time information about the condition of the ET.

2.4.2 Onboard Handheld Camera ET Analysis *(Task #6)*
(STS-57-03-01 through 37)

STS-57 crew performed DTO-312 acquiring 37 views of the external tank (ET) from a single roll of 35 mm film. Apparent damage to the external tank thermal protection system (TPS) on the intertank acreage was observed. The entire ET was photographed except the side away from the FSS as the vehicle sits on the pad, or the +Y axis.

The photographs were taken by Jeff Wisoff using Nikon F4 camera with a 300 mm lens and a 2x extender (Method 3). The first photograph was taken 6 minutes and 7 seconds

after ET separation while the ET was at a distance of 933 meters from the Orbiter. The last photograph was taken at 11 minutes and 55 seconds after ET separation while the Orbiter was 2,234 meters from the Orbiter. At the start of photography, the ET tumbled at 2.2 degrees per second. The analysis results were reported to the Mission Evaluation Room (MER) Manager and to the standard distribution. The results of this analysis are located in Appendix D, Task #6.

Figure 2.4.2 Onboard Handheld Camera View of the ET

Nine to ten divots were visible on the ET intertank TPS acreage to the right of the forward LSRB attach point (1). Five divots were visible on the LH2 intertank between the ET access door and the LSRB forward attach point (2). Two large divots were seen

on the lower LH2 intertank interface. One was located below the LSRB forward attach point (3) and the other was on the -Z side of the ET. Multiple divots were seen near the ET/Orbiter attach bipod (4). Pieces of white debris were visible in the background on many of the frames (5).

A divot was visible on the aft vertical thrust strut near the ET LO2 umbilical. This damage is being worked as part of the divot problem reported on the STS-56 ET (inflight anomaly number STS-56-T-001). The area surrounding the strut is more clearly visible from 35 mm umbilical well camera (see Section 2.4.4).

A single large divot on the LH2 intertank interface below the ET access door (-Z side) measured 12 inches and a single large divot below the LSRB forward attach point (-Y side) measured 19 inches. The 9 divots to the right of the LSRB forward attach point were measured to range between 6 and 7 inches. The ET/Orbiter separation velocity was determined to be 3.74 meters per second which is slightly less than that seen on recent missions.

2.4.3 16 mm Umbilical Well Camera Views of the SRB and ET Separation *(Task #5)*

The 16 mm motion picture film taken from the Orbiter LH2 umbilical was reviewed. The focal length of the camera lens was 5 mm. This 16 mm motion picture film showed LSRB and ET separation along with the normal venting and debris associated with these events.

The 16 mm film sequence of the LSRB separation has good exposure and focus. Multiple pieces of light colored TPS debris of various shapes and sizes are visible before, during, and after the separation of the SRBs. Chipping and erosion of the TPS on the base of the electrical cable tray and the aft ET/Orbiter and ET/LSRB attach struts are visible. A piece of insulation on the base of the electrical cable tray was seen to detach prior to SRB separation. The loose end of this insulation eventually broke off and fell from view. The LSRB separation appeared normal. A dark piece of debris was visible on the ET side of the LSRB/ET attach just after SRB separation. There were three bright marks or reflections visible on the LSRB attach on the face exposed after the LSRB detached from the external tank.

The initial exposure of the 16 mm film during the second film segment of the separation of the external tank was very dark because the sun was behind the ET. The view improved during the umbilical well purge. Multiple pieces of white debris (ice/frost) and white vapors were in view. After the umbilical purge, the white debris continued to be in view although the view was again very dark. Periodically, orange or light colored vapors come into view that were probably caused by RCS firings.

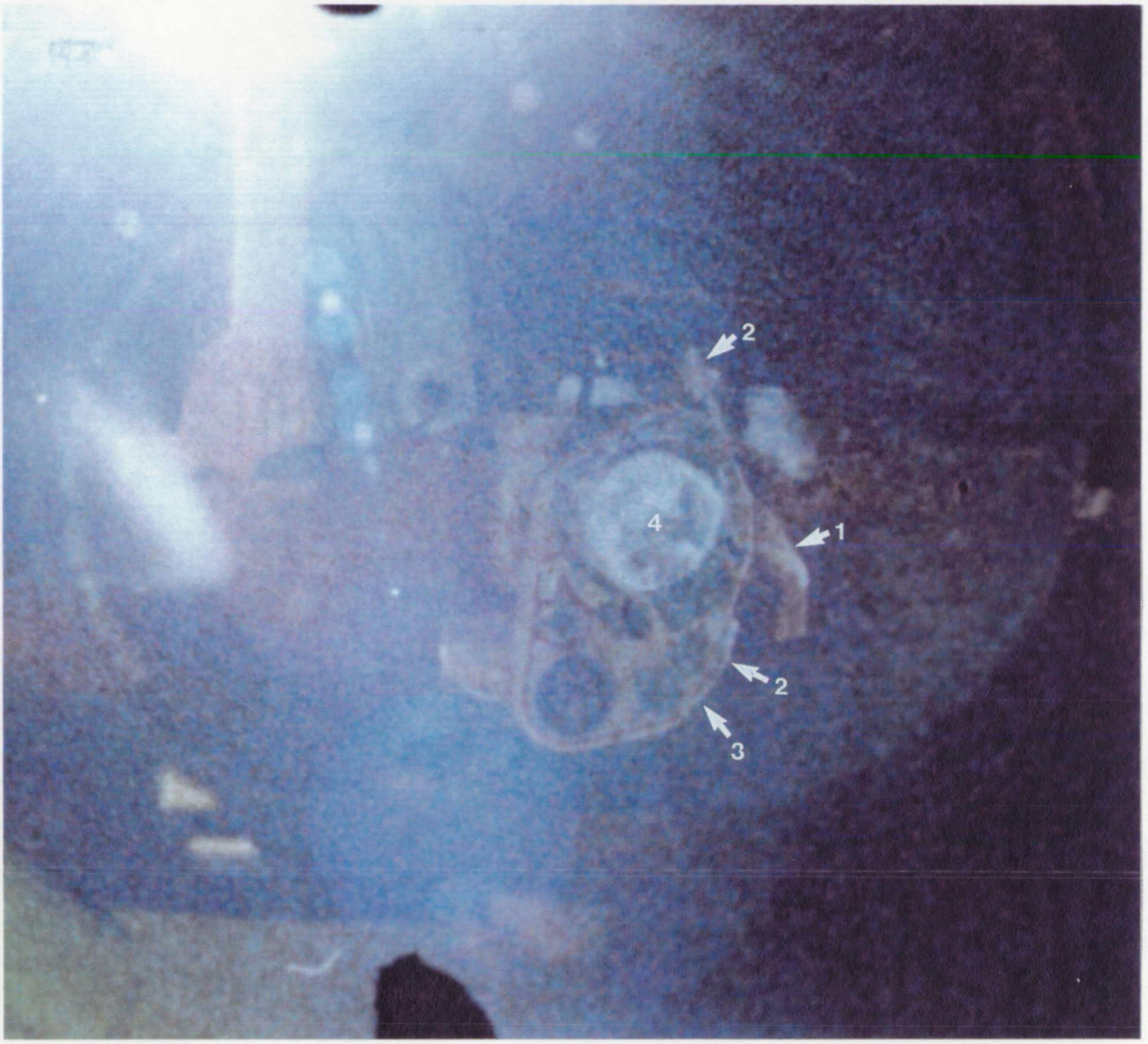


Figure 2.4.3a 16 mm Camera View of the ET LH2 Umbilical

After the external tank separated from the Orbiter, a piece of loose insulation or foam was visible on the view of the inboard side of the ET LH2 umbilical. This piece of foam was over 20 inches long and 4 inches wide as determined by comparison to known structures on the face of the LH2 umbilical (1). Two possible pieces of detached white RTV were visible on the inboard and forward sides of the LH2 umbilical (2). A segment of the red RTV seal that surrounds the outer border of the LH2 umbilical appeared to be missing near the four inch line connect (3). The large circle of ice in the LH2 seventeen inch line orifice is an expected occurrence and has been seen on the previous mission umbilical well films (4).

A slender piece of white debris that appeared to be flexing was visible on the left side of the film view of the ET LH2 umbilical after ET separation. This may be a piece of white RTV that came from the LH2 umbilical.

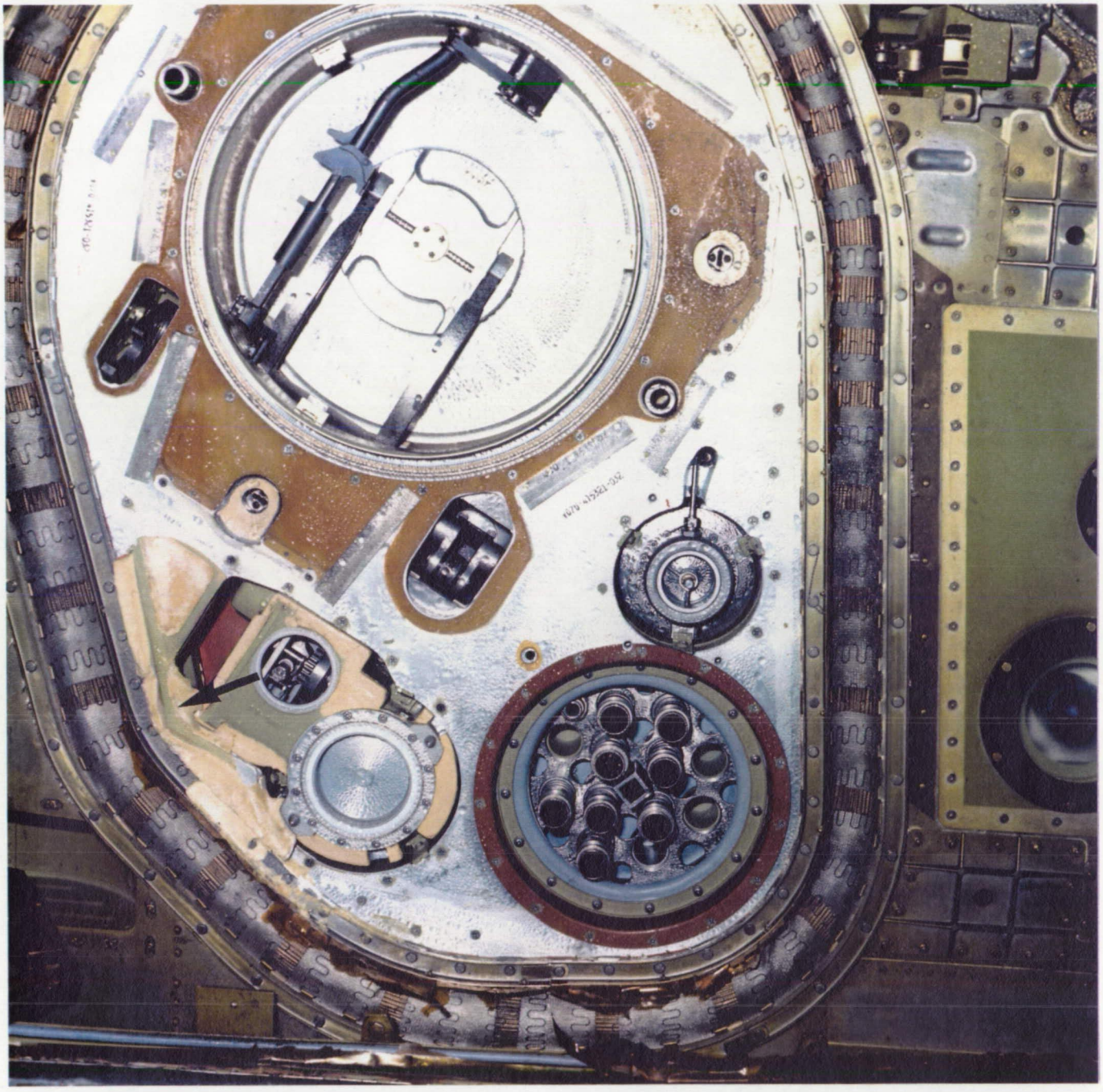


Figure 2.4.3b **Closeout Picture of the LH2 Umbilical taken by the KSC Debris Team**

A picture of the Orbiter LH2 umbilical (Figure 2.4.3b) taken by the KSC Debris Team after landing indicated that approximately 10 inches of foam material remained near the four inch line connect. The 16 mm umbilical well camera film of the ET LH2 anomalies was shown to the JSC Propulsion and Power Division/EP2 engineers. The JSC engineers suggested that the closeout foam placed near the four inch line connect prior to launch

may be sticking causing some of the RTV and foam to be pulled loose during ET separation.

Very small pieces of debris were noted inside the umbilical well camera housing. Pieces of white debris continued to move across the field of view until the end of the film. The ET had a slight lean to the right by the end of the film.

Poor imagery due to the back lighting from the sun significantly hindered analysis. The detailed screening sheets are located in Appendix D, Task #5.

2.4.4 35 mm Umbilical Well Camera Views of the ET Separation *(Task #5)*

Sixty-four well focused 35 mm frames were obtained of the external tank separation. The first six frames were too dark for analysis because the sunlight was blocked by the external tank. Frames 7 through 27 were dark but usable. A lens flare hampered analysis after the twenty-seventh frame. The 35 mm umbilical camera screening sheets are located in Appendix D, Task #5.

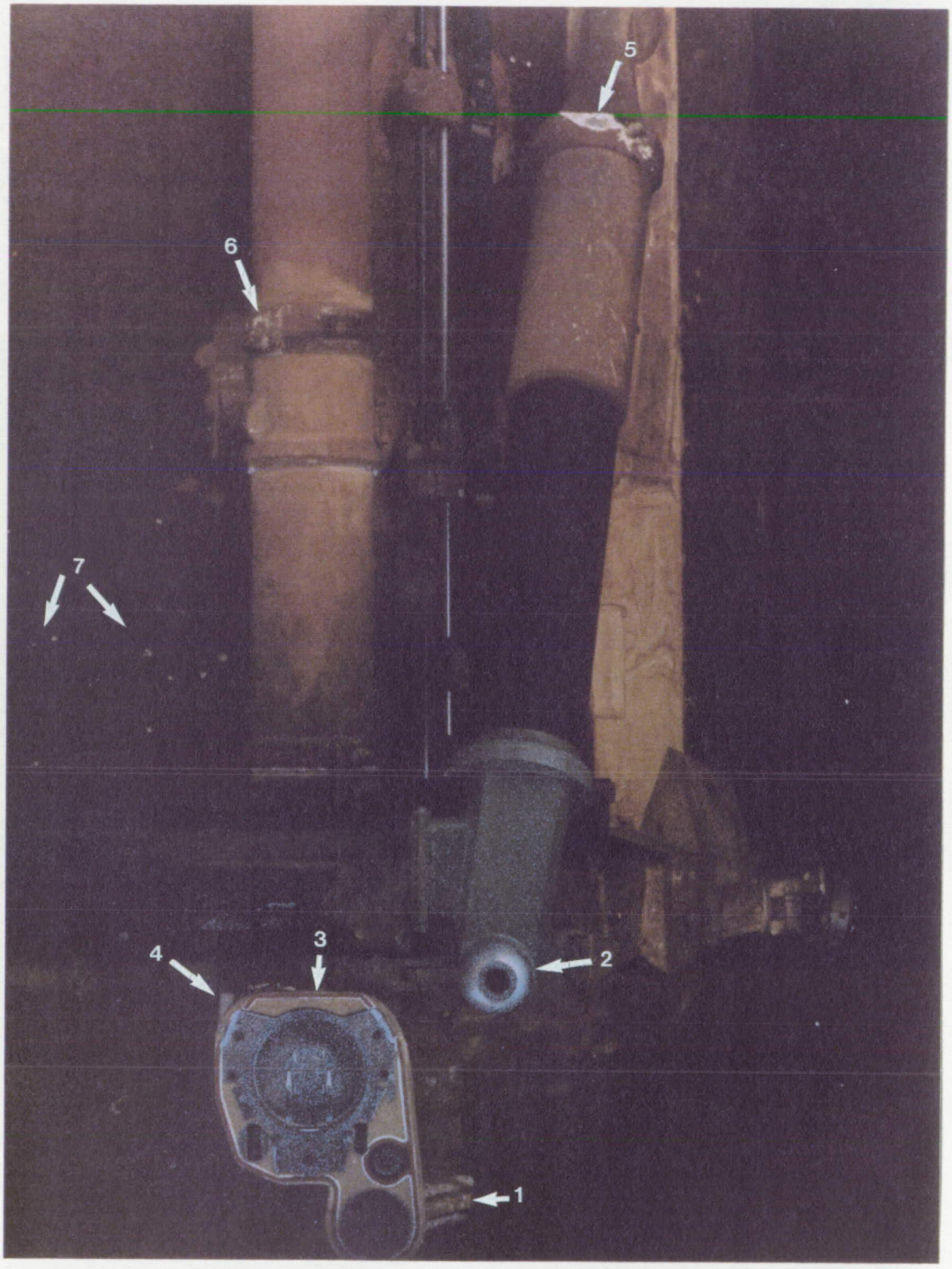


Figure 2.4.4a 35 mm Camera View of the ET LO2 Umbilical

TPS erosion was visible on the right side of the LO2 umbilical (1). A red seal around the EO-3 fitting above the LO2 umbilical was detached (2). The lightning contact strip at the

forward end of the LO2 umbilical appeared to be missing (3). JSC engineers were consulted and according to their information the electric contact strip was present prior to launch. Possible TPS damage or a piece of loose insulation was visible near the upper left corner of the LO2 umbilical (4). This possible loose insulation may be related to a three inch piece of ET foam that was found during the post landing inspection of the Orbiter LO2 umbilical by the debris inspection team. This three inch piece of foam adhered to a tile on the LO2 door near the hinge line according to the post landing inspection team report. A section of TPS was missing from the forward end of the ET aft +Y LO2 vertical thrust strut (5). The missing TPS appeared to have left a deep divot. A primed or bare metal surface was visible at the center of the missing TPS area. An engineer at MSFC stated that the missing TPS is being worked as part of the divot problem reported on the STS-56 external tank (inflight anomaly number STS-56-T-001). TPS erosion was visible on a aft bracket over the LO2 feedline at approximately station 1958 (6). Small, white marks were visible on the TPS to the left of the LO2 feedline at the base of the LH2 tank (7).

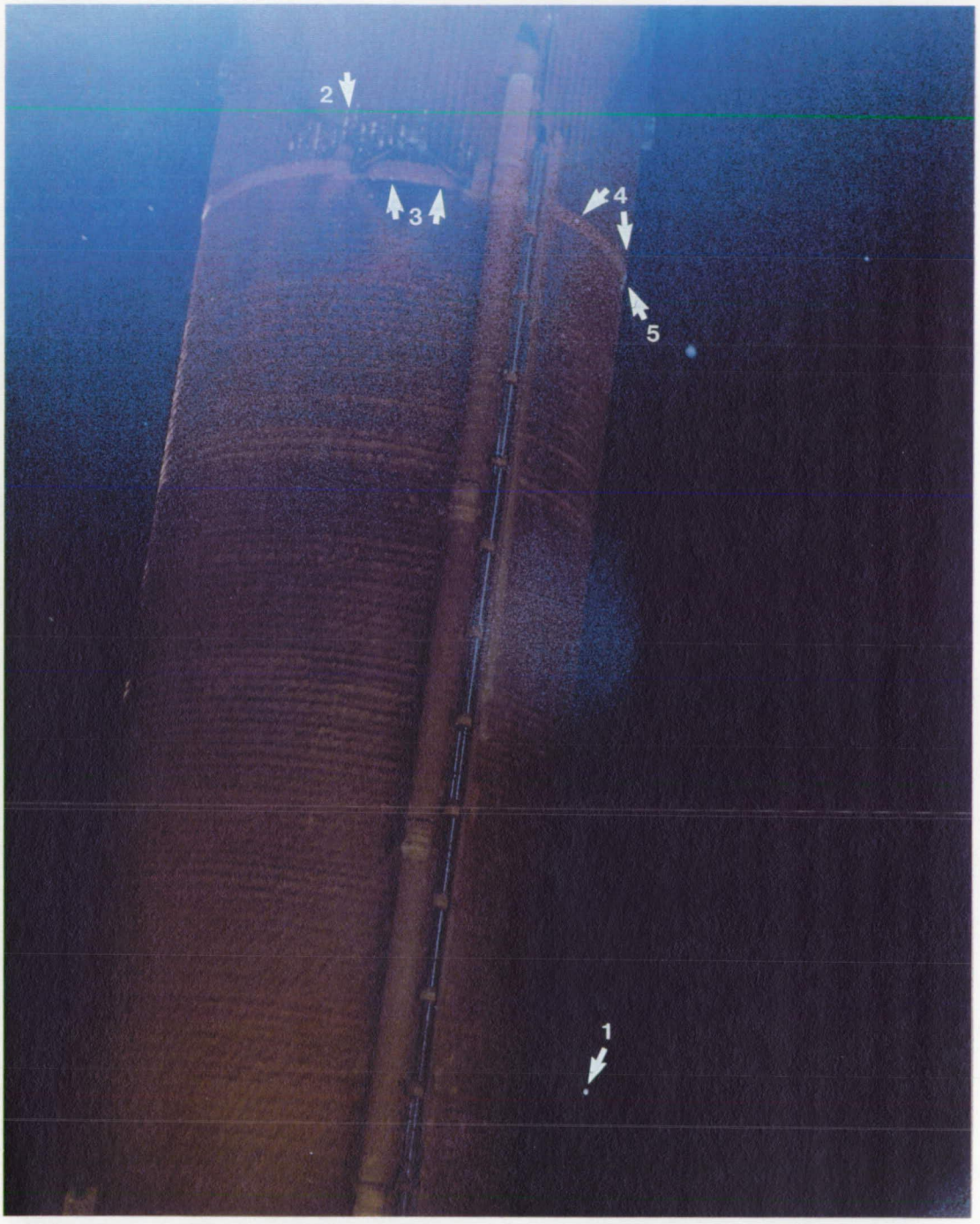


Figure 2.4.4b **35 mm Camera View of the Bipod and LH2 Tank/Intertank Region of the External Tank**

Multiple pieces of white debris were imaged between the camera and the external tank. The white debris appeared to be ice (1). Multiple white "popcorn" marks were visible on the intertank stringers forward of the bipod (2). Several small white marks or divots were visible between the bipod legs on the LH2 tank/intertank closeout flange (3). Two divots less than six inches in size were visible on the intertank closeout flange to the right of the

LO2 feedline (+Y axis) (4). One divot less than six inches in size was visible on the LH2 tank TPS just below the intertank/LH2 tank closeout flange on the +Y axis (5).

2.5 On Orbit Events

No on orbit events were requested to be analyzed this mission

2.6 Landing Events

2.6.1 Landing Sink Rate from Video *(Task #3)* *(Camera KTV-33)*

Camera TV-33 was used to determine the video nose gear and main gear sink rate for STS-57. For both the main gear sink rate and the nose gear sink rate, a known length of Orbiter black tile was used as the scalar reference. This scalar reference was 78 inches in length. After the distance values were determined and scaled, a trend of these distances was calculated to smooth the data and determine the sink rate from the slope of the data.

Left main gear sink rate was determined to be 19.9 inches per second or 1.7 feet per second and the right main gear sink rate was determined to be 17.5 inches per second or 1.5 feet per second.

Nose gear sink rate was determined to be 1.2 feet per second, which is consistent with the film analysis.

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

2.6.2 Landing Sink Rate Analysis Using Film *(Task #3)* *(Cameras EL-9, EL-12)*

Camera EL-9 film viewing the aft end of the Orbiter was used to determine the sink rate of the main gear. The good view provided by this camera allowed the observation that both inboard tires contacted the runway surface prior to the respective outboard tires. The left inboard tire (44.5 inches) was used to scale the measurements. Data was gathered for 1.019 seconds prior to landing through touchdown. The motion of the wheel was measured and a linear regression was applied on this normalized vertical distance versus time data to find the actual rate. The main gear sink rate was determined to be 1.6 feet per second which is well within the current threshold limits.

Nose gear touchdown occurred approximately 18 seconds after main gear touchdown. Camera EL-12 viewing the left side of the Orbiter near the point of nose gear touchdown was used to scale the measurements. Data was gathered for the 1.967 seconds prior to nose gear touchdown. The distance between the nose wheel and the runway surface was computed and a linear regression was applied on this normalized vertical distance versus time data to find the actual rate. The nose gear sink rate was determined to be 1.7 feet per second.

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

2.6.3 Drag Chute Performance *(Task #9)* *(Cameras EL-7, EL-9, EL-10)*

The landing of Discovery at the end of mission STS-57 marked the ninth use of the Orbiter drag chute. All components of the drag chute appeared to deploy as expected. Standard analysis of the drag chute angles as a function of time was performed using the views from the film cameras EL-7, EL-9 and EL-10. This analysis is used to support the improvement of the aerodynamic math models currently in use. The maximum horizontal chute deflection was approximately 5.1 degrees.

The following drag chute times were acquired from cameras EL-9, EL-10, EL-12, and EL-19.

12:52:24.452 UTC	Drag chute initiation
12:52:25.216 UTC	Pilot chute full inflation
12:52:27.071 UTC	Drag chute inflation in reefed configuration
12:52:30.326 UTC	Drag chute inflation in disreefed configuration
12:52:56.208 UTC	Drag chute release

Graphical representations of the results of this analysis may be found in Appendix D, Task #9.

2.7 Other Normal Events

Other normal events observed include: ice buildup on the SSME vent nozzles; slight vapor from the gaseous oxygen (GOX) vent on the ET and frost on the vent louvers, flexing of the base heat shield at SSME startup; slight motion of the body flap and elevons between SSME ignition and liftoff; ice and vapor from the GUCP during SSME startup and arm retraction; pressure waves visible in the SLV exhaust cloud at liftoff; vapor from drain hole on trailing edge of the rudder speed brake at tower clear; debris in the exhaust cloud at the pad after liftoff; slight roll maneuver overshoot and adjustment; white puffs in SSME exhaust plume during and after the roll maneuver; ET aft dome outgassing and vapor from the SRB stiffener rings after liftoff; charring of the ET aft dome during ascent; minor wind shear in the SLV exhaust plume after liftoff; SRB plume brightening.

2.8 Launch Facility Events

Normal events related to the launch facilities are FSS deluge water spray activation and MLP water dump activation.

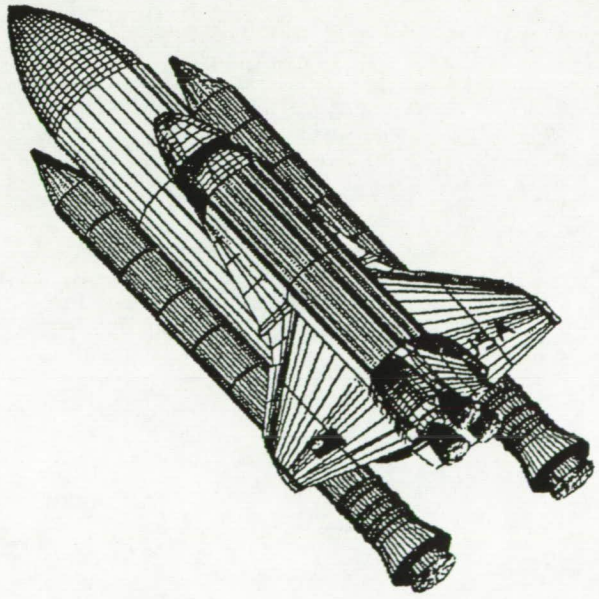
Water leaks in the MLP J-Pipes near holddown posts M-3 and M-4 were observed.

Appendix B. MSFC Photographic Analysis Summary

NASA
National Aeronautics and
Space Administration

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

SPACE SHUTTLE
ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT
STS-57



ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

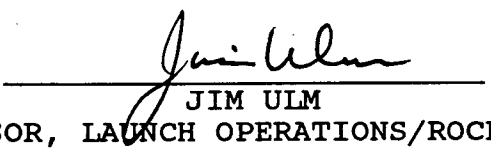
STS-57

FINAL

PREPARED BY:

B. EPPS, J. HIXSON, B. VIGER
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:



JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

APPROVED BY:

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

STS-57 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.

I. INTRODUCTION

Space Shuttle Mission STS-57, the fourth flight of the Orbiter Endeavour was conducted June 21, 1993 at approximately 8:07 A.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-57 included, but were not limited to the following:

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

There was one special test objective for this mission:

a. DTO-0312, ET photography after separation

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-four of fifty-seven requested cameras as well as video from all twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-57.

CAMERA DATA RECEIVED FOR STS-57

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	3	4	6
Tracking	0	13	11
Onboard	3	2	0
Totals	35	19	24

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-57 was considered good. Tracking camera coverage was degraded due to cloud cover and atmospheric conditions. Cameras E-54 and E-213 provided no data and were not shipped to MSFC. Camera E-57 did not operate due to a mechanical failure. Timing information on camera E-3 was invalid. Timing data was lost on cameras E-1 and E-4 after approximately T+6 seconds.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly but ran out of film prior to water impact. The astronauts carried a 35mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. Thirty-seven frames of data were recorded. A 35mm camera was mounted in the right umbilical well to record ET separation and ET TPS integrity. Sixty-four frames of data were recorded. A 16mm motion picture camera was mounted in the left umbilical well to record during and after 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; and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors and purge barrier material. Body flap and inboard right elevon motions were noted during ascent.

From the on-board cameras, typical charring of aft dome noted, BSM burn scar noted and typical TPS erosion and debris (ice/frost) were noted.

b. SRB Holddown Post M-2 Debris

Figure 1 is a film frame taken from camera E-8 showing the first of two events of frangible nut material falling from the hold-down post M-2 hole. These debris behaved typically of previously observed frangible nut material, falling down into the shoe area without striking any flight hardware.

c. ET TPS Divots

Figure 2 shows the "popcorning" of the TPS forward of the bipod strut on the intertank and the one large divot aft of the bipod strut on the LH2 tank. Figure 3 shows approximately ten divots on the intertank near the LSRB forward attach point and the one large divot at the LO2 tank/intertank interface. Figure 4 shows the divots noted on the leading edge of the thrust strut near the ET base.

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	172:13:07:21.998
M-2	E-8	172:13:07:21.998
M-5	E-12	172:13:07:21.997
M-6	E-13	172:13:07:21.996

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 32 inches. Figure 5 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera E-79.

c. SRB Separation Time:

SRB separation time for STS-57 was determined to be 172:13:09:26.78 UTC as recorded by camera E-207.

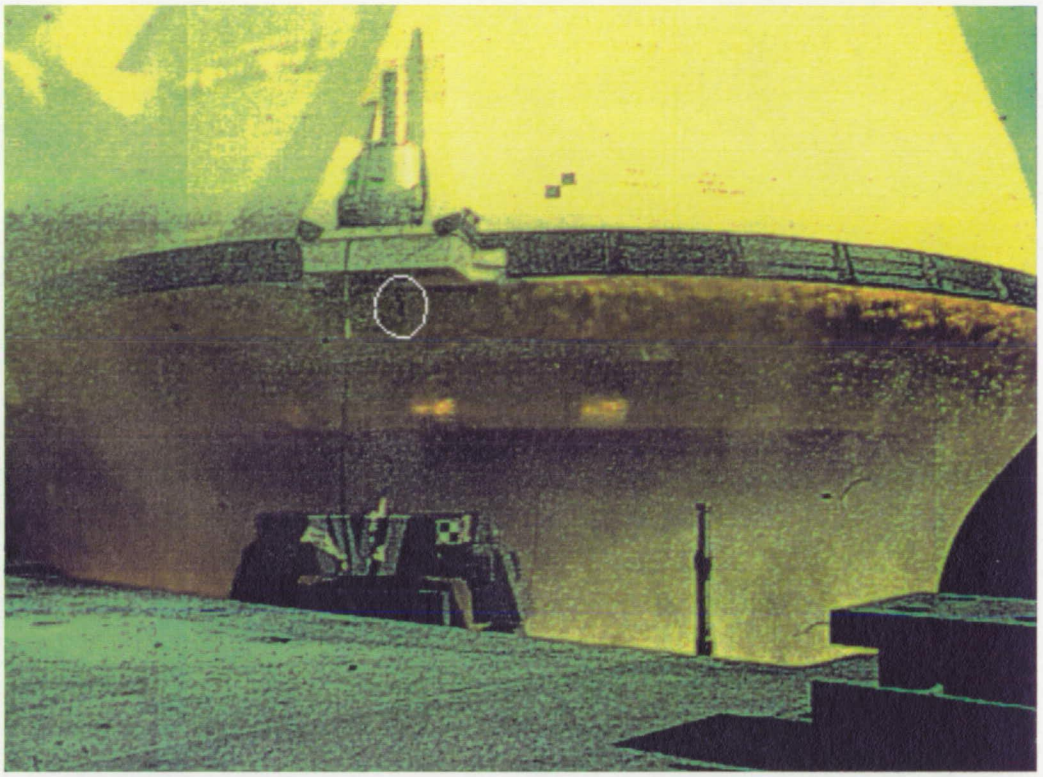


Figure 1.

Frangible nut material from holddown post M-2.

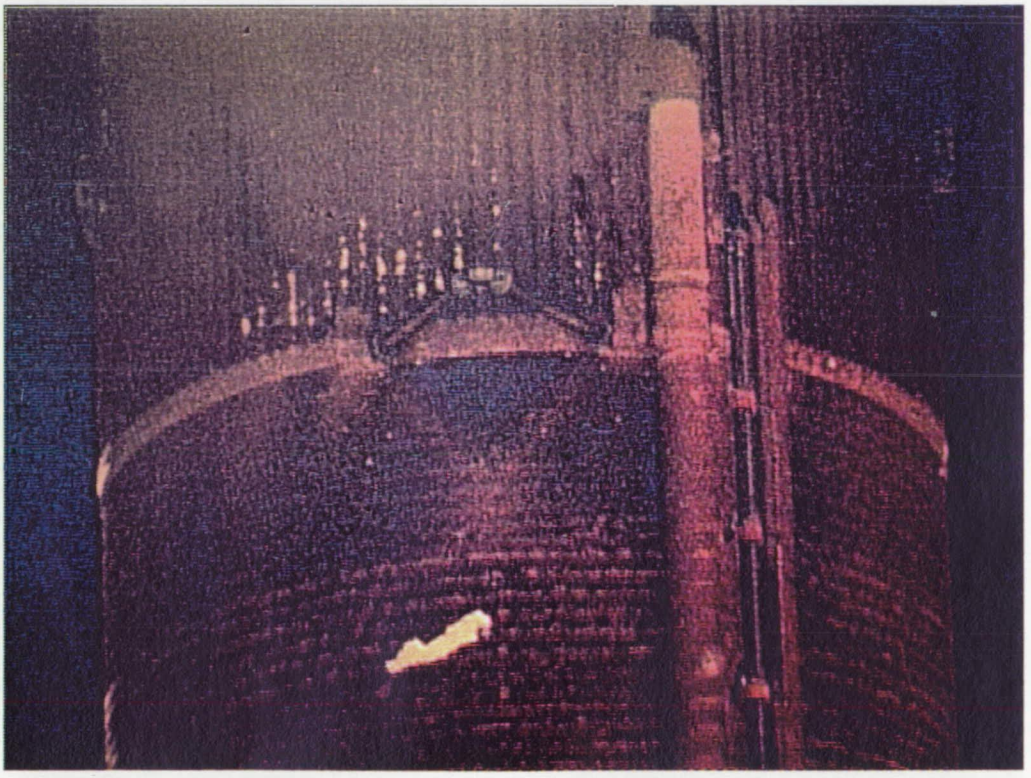


Figure 2.

Popcorning of TPS near bipod strut and large divot on LH2 tank.

Figure 3.

Divots on intertank near left SRB attach point.

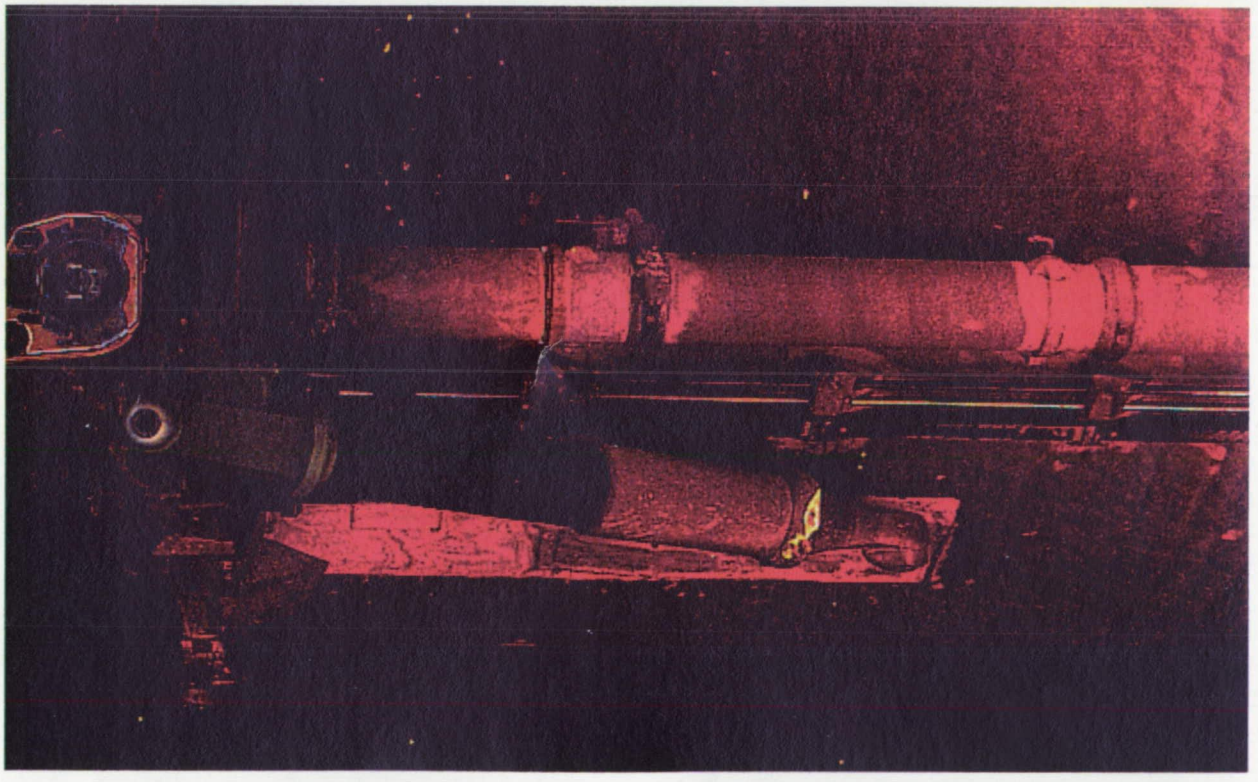
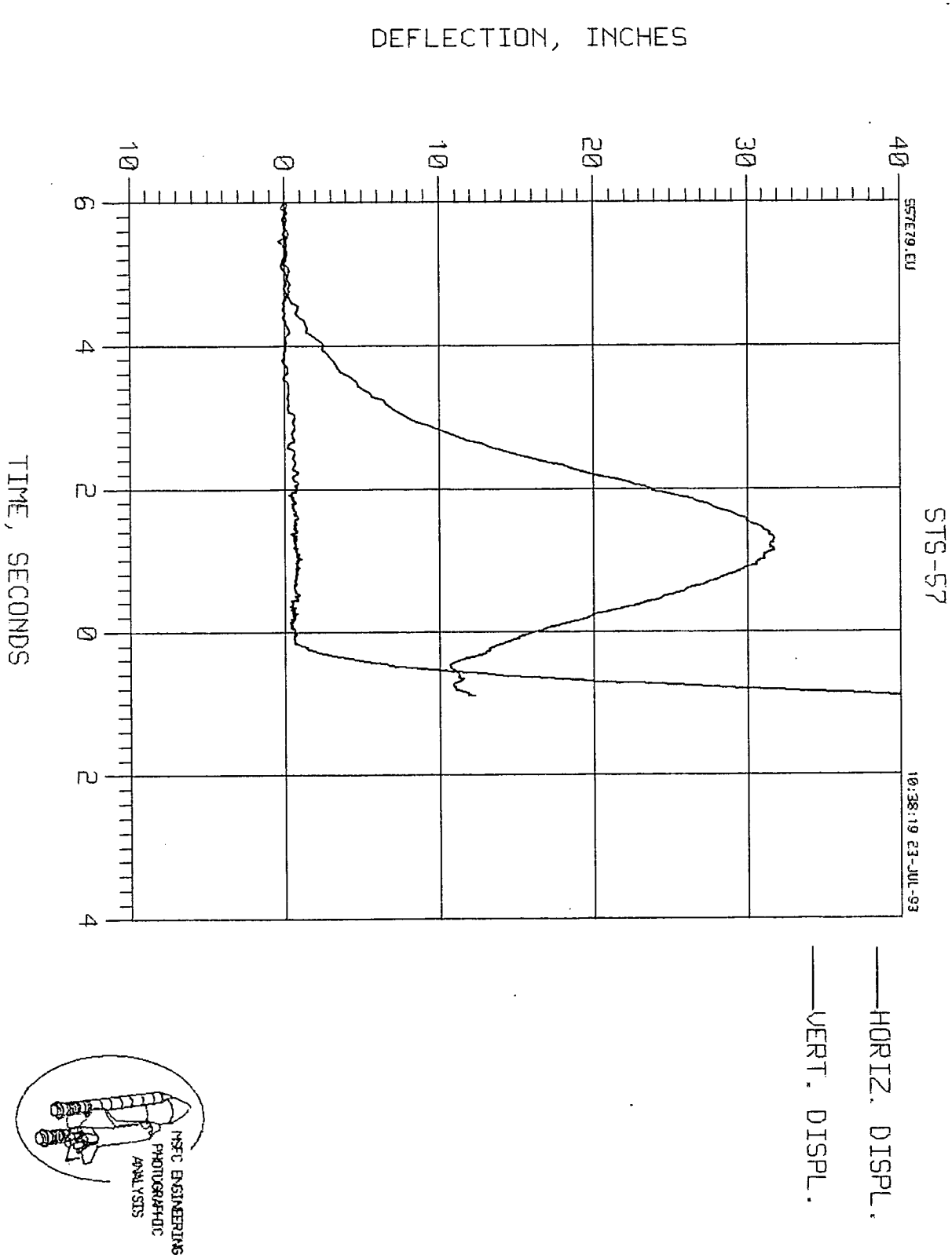


Figure 4.

Divots on thrust strut.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ET TIP DEFLECTION
STS-57
HORIZ. DISPL.
VERT. DISPL.
MSFC ENGINEERING
PHOTOGRAPHIC
ANALYSIS

Figure 5

Appendix C. Rockwell Photographic Analysis Summary

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

Rockwell International

August 2, 1993

In Reply Refer to 93MA2128

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-57 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).

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-57 launch conducted on June 21, 1993, at approximately 6:07 a.m. (PDT) from the Kennedy Space Center (KSC) and for the landing on July 1, 1993 at KSC at 5:52 a.m. (PDT).

Rockwell received launch films from 82 cameras (58 cine, 24 video) and landing films from 24 cameras (14 cine, 10 video) to support the STS-57 photographic evaluation effort. Three films, E54, E57 and E213 were not available due to camera malfunction.

All ground cameras coverage for this mission including coverage on the MLP, FSS and tracking cameras were good, however, the tracking film cameras and videos was hampered by clouds.

Overall, the films showed STS-57 to be a clean flight. Several pieces of ice from the ET/ORB umbilicals were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver.

(Packing Sheet No. DM93-15214)

Vapor was observed in the vicinity of the rudder/speed brake at liftoff. Charring of the ET aft dome, recirculation and brightening of the SRB plumes were visible and normal. Booster separation Motor (BSM) firing and SRB separation also appeared to be normal, although clouds hampered the analysis of many of the long-range tracking cameras.

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

STS-57 was the sixteenth flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up.

No major or significant events were observed or identified. Two items that merit mentioning (not considered an anomaly) are the condensation "puffs" and the three inch piece of ET foam found during the post landing inspection of the Orbiter LO_2 umbilical by the debris inspection team. These events and other events noted by the Rockwell film/video users during the review and analysis of the STS-57 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. A question was raised regarding the intermittent condensation "puffs" observed on the Space Shuttle during transonic flight at the Orbiter crew module and payload bay area. The issue was whether condensation that formed around the Orbiter was related to pressure spikes measured in the payload bay area on previous missions. Analysis showed that during transonic flow, the flow expansion around the Orbiter will cause local pressure and temperature to drop. When the local temperature drops below the dew point the condensation phenomenon occurs. This event causes no adverse effects on the Orbiter.

   These conclusions were derived from an analytical calculation performed, based on the prelaunch weather balloon data, prelaunch estimate of the STS-57 trajectory, and the aerodynamic pressure distributions on the Orbiter during ascent. No follow on work is scheduled for this issue.

2. Review of the 35mm Umbilical Well camera views of the ET separation shows possible TPS damage or a piece of loose insulation near the upper left corner of the LO_2 umbilical. This possible loose insulation may be related to the three inch piece of ET foam that was found during the post landing inspection of the Orbiter LO_2 umbilical by the debris inspection team. No additional follow on work is scheduled for this issue.

   On the 16mm LH_2 Umbilical Well Camera film of the SRB and ET separation a piece of loose insulation or foam was noted on the inboard side of the ET LH_2 umbilical and possibly two pieces of detached white RTV are visible on the inboard sides of the LH_2 umbilical. Also, a piece of red RTV seal around the outer border of the LH_2 umbilical appears to be missing near the four inch line connect. JSC and RI/DNY engineers suggested that this may be caused by the close out foam placed near the four inch line connect, prior to launch, sticking and pulling some of the RTV and foam loose during ET separation. No follow on work is planned.

3. On cameras E-2, E-3, E-19 and E-20, a white flash was noted in the SSME #1 plume at liftoff. Flashes have been observed on previous missions and are probably caused by small amounts of contaminants in the main engine. No follow-up action is planned.

4. Orange vapor (possibly free burning hydrogen) was seen below the SSME's and the body flap just prior to SSME ignition on cameras (OTV-163, OTV-170, OTV-171, E-2, E-19 and E-20. 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. On camera E-8, a metallic appearing piece of debris was noted falling from the DCS stud hole of the right SRB holddown post M-2 at liftoff. This debris did not appear to strike the vehicle. No follow-up action is planned.

6. On cameras E-42 and E-50, the GH_2 Vent Arm retraction lanyard did not reel in and was slack. No follow-up film analysis action is planned.

7. Multiple pieces of debris particles were seen falling aft of the Orbiter during and after completion of the roll maneuver on cameras E-212, E-218, E-222, and E-223. The debris was probably RCS paper covers or ice from the ET/Orbiter umbilicals. No follow-up action is planned.

8. Flares and flashes seen in the SSME exhaust plume (E-207, E-212, E-222) during ascent. These observations have been seen in the SSME plumes on previous missions and are understood to be burning of propellant impurities including RCS paper covers. No follow-up action is planned.

9. The following events have been reported on previous missions and observed on STS-57. These are not of major concern, but are documented here for information only:

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

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

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

11. Cameras E7-16 and E27-28 - 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-57 occurred on runway 33 at the KSC Shuttle Landing Facility. Good video and film coverage were obtained and no anomalous events were observed. The flight marked the ninth 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.

    During the post-landing inspection slight tile damage on the base of the vertical stabilizer stinger above the door for the drag chute was noted. No follow-up action has been requested.

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

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A Debris/Ice/Thermal Protection System (TPS) assessment and integrated photographic analysis was conducted for Shuttle mission STS-57. Debris inspections of the flight elements and launch pad were performed before and after launch. Ice/frost conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and integrated photographic analysis of Shuttle mission STS-57, and the resulting effect on the Space Shuttle Program.

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Thermal Protection System (TPS) Photographic Analysis

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