NASA Technical Memorandum TM 107553

Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-47

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National Aeronautics and
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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-47

September 12, 1992

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FOREWORD

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

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

Shuttle Mission STS-47 was launched at 10:23 a.m. local 9/12/92

1.0 Summary

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 11 September 1992. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (2nd flight), ET-45 (LWT 38), and BI053 SRB's. There were no vehicle or facility anomalies.

The vehicle was cryoloaded for flight on 12 September 1992. There were no Launch Commit Criteria, OMRS, or NSTS-08303 violations. There were no ice 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 during the cryoload. No unusual vapors or cryogenic drips were visible during tanking, stable replenish, and launch. A 4-inch crack was present in the forward surface of the -Y ET/SRB vertical strut cable tray near the longeron closeout interface. There was no offset and no ice/frost in the crack. The crack occurred in an area where the stress relief cut had been eliminated by design at the factory. The condition was acceptable for launch per NSTS-08303 and CR S041254C. An IPR was taken against a 0.40L x 0.15W x 0.0625D-inch dent, or cavity, on the inboard edge of Orbiter LH RCC panel #9. The IPR was dispositioned to fly-as-is.

A debris inspection of Pad 39B was performed after launch. No flight hardware was found. EPON shim material on the south holddown posts was intact and bonded to the shoes. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. The GH2 vent line had latched properly. Damage to the facility overall was minimal.

A total of 137 film and video items 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 ordnance debris fell from any of the HDP DCS/stud holes. All T-0 umbilicals operated properly. On-orbit imagery revealed nine divots in the ET LH2 tank-to-intertank flange closeout, 2 divots in the LH2 tank acreage, some TPS damage to the LO2 ET/ORB umbilical and cable tray, and one 14-16 inch divot in the intertank acreage between the bipods. The divot in the intertank acreage had the greatest potential threat to Orbiter tiles and was taken as an IFA. A copper-colored object drifted away from the LH2 ET/ORB umbilical after ET separation from the Orbiter. The origin of the object, a washer or spacer, has not been determined. Orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal. A 2-4 knot crosswind blew the drag chute eastward relative to the Orbiter and caused the nose to yaw left (westward). Active steering and braking was required to bring the vehicle back on runway center line. Since this was an unexpected controllability concern, an IFA was taken.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The RH frustum had 42 MSA-2 debonds over fasteners and one 2-inch diameter area of missing TPS on the -Y axis at the 275 ring frame. The LH frustum had 25 MSA-2 debonds over fasteners and was missing MSA-2 (1.5-inch diameter) from one location between the +Y and +Z axes on the 381 ring frame. A 6" x 3" piece of K5NA was missing from the aft stiffener ring. Though the remaining material showed signs of delamination, the surfaces were not sooted indicating the material was most likely lost at water impact. All Debris Containment System (DCS) plungers were seated properly. Pieces of EPON shim were missing from HDP #4 and HDP #7. The material was lost prior to water impact and exhibited a sooted/charred substrate.

A detailed post landing inspection of OV-105 (Endeavour) was conducted on 20 September 1992. The Orbiter TPS sustained a total of 108 hits, of which 11 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 47 hits, of which 3 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 Orbiter TPS debris hits and the number of hits one inch or larger were less than average. The EO-3 (LO2) ET/Orbiter separation device plunger was obstructed by two ordnance fragments and did not seat properly. The EO-1 and EO-2 separation devices appeared to have functioned properly. No flight hardware was found on the runway below the umbilicals when the ET doors were opened.

This flight marked the third use of the Orbiter drag chute. The drag chute appeared to have functioned nominally. However, three tiles on the LH edge of the vertical stabilizer "stinger" suffered significant damage/material loss due to contact with the riser lines during chute deployment. Another tile, on the lower (-Z) RH edge of the drag chute opening, was slightly damaged by separation of the chute compartment door. All drag chute hardware was recovered and showed no signs of abnormal operation.

A variety of residuals were present in the Orbiter window samples and indicated sources such as Orbiter TPS, SRB BSM exhaust residue, natural landing site products, organics, and paint. Results of residual data do not indicate a single source of damaging debris as all of the materials have been noted previously in post-landing sample reports. These residual sample data also gave no indication of debris trends when compared to data from previous missions.

A total of eleven Post Launch Anomalies, including two IFA candidates, were observed during this mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Debris/TPS/Photographic Analysis Team briefing for launch activities was conducted on 11 September 1992 at 0830 hours with the following key personnel present:

S. Higginbotham	NASA - KSC	STI, Ice/Debris Assessment
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
M. Bassignani	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
R. Seale	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
Z. Byrns	NASA - JSC	Level II Integration
S. Copsey	MMC - MAF	ET TPS Testing/Certif
J. Stone	RI - DNY	Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Vehicle Integration
C. Cooper	MTI - LSS	SRM Processing
S. Otto	MMC - LSS	ET Processing

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

2.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

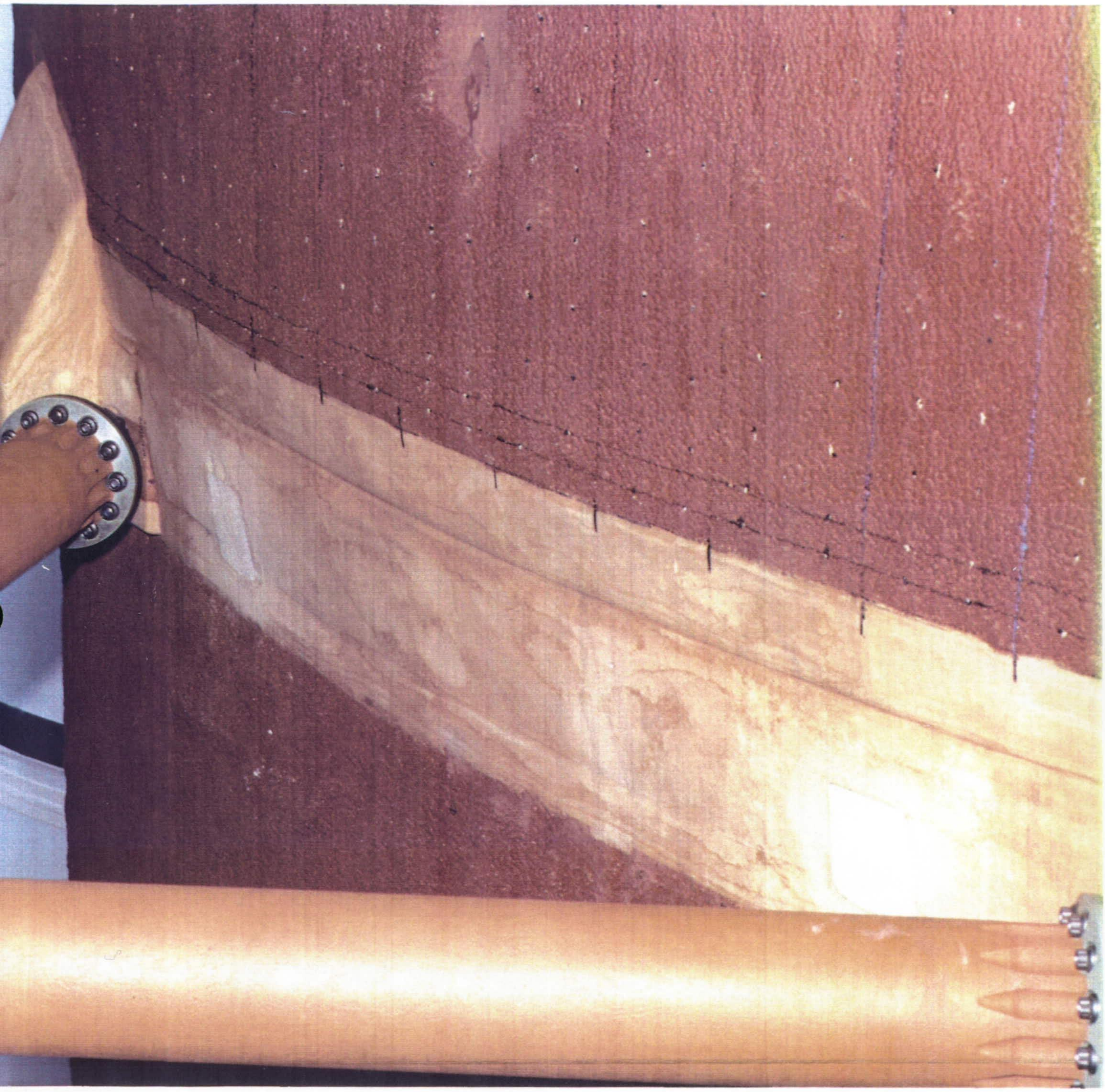
A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 11 September 1992 from 0930 - 1130 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (2nd flight), ET-45 (LWT 38), and BI053 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload and launch, tygon tubes for hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical. The tygon tubes are intended to remain in place during cryogenic loading and be removed by the Ice Team during the T-3 hour hold.

There were no significant vehicle anomalies.

Three loose bolts along with small pieces of debris, such as tie-wraps, TPS trimmings, rope, writing pen, and a handrail securing pin, were picked up by the Inspection Team. Debris on the holddown post #5 and #6 haunches were cleared by MLP deck operations technicians.

All discrepancies were corrected real-time by Pad Operations and no items were entered in S0007, Appendix K.



Pre-flight configuration of the bipod jack pad closeouts, the intertank TPS acreage, and the LH2 tank flange closeout. Post ET separation photography would reveal the loss of TPS from the intertank acreage and the LH2 tank flange closeout.

LH (-Y) vertical strut/cable tray TPS covering prior to cryogenic fuel loading. Cracks have appeared in this general area after cryoload due to the elimination of a stress relief gap as part of a manufacturing process enhancement change.

Due to OSHA/safety concerns, semi-permanent handrails were installed at the FSS 95 foot level-to-MLP deck crossover. The handrails remained in place during launch and did not become a debris issue.

3.0 LAUNCH

STS-47 was launched at 12:14:23:00.010 GMT (10:23:00 a.m. local) on 12 September 1992.

3.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 12 September 1992 from 0520 to 0730 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:	75.9 Fahrenheit
Relative Humidity:	91.0 %
Wind Speed:	4.6 Knots
Wind Direction:	303 Degrees

A hand-held Minolta/Land Cyclops radiometer was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

3.2 ORBITER

No Orbiter tile anomalies were observed. An IPR was taken against a .40L x .15W x .0625D-inch dent, or cavity, on the inboard edge of the LH RCC panel #9. The IPR was dispositioned to fly as-is. All RCS thruster paper covers and water spray boiler plugs were intact. Less than usual ice/frost was present at the SSME heat shield-to-nozzle interfaces. Condensate was present on all SSME heat shields and on base heat shield tiles. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

3.3 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 Cyclops radiometer recorded RH and LH SRB case surface temperatures between 75 and 79 degrees Fahrenheit (F). In comparison, temperatures measured by a portable Shuttle Thermal Imager (STI) infrared scanning radiometer ranged from 76 to 80 degrees F and the SRB GEI (Ground Environment Instrumentation) measured temperatures ranging from 77 to 82 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 82 degrees F, which was within the required range of 44-86 degrees F.

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

TIME: 0515 - 0630 EDT
DATE: 9/12/92
VEH. STS- 47

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0

MEASUREMENTS TAKEN WITH CYCLOPS HAND-HELD RADIOMETER

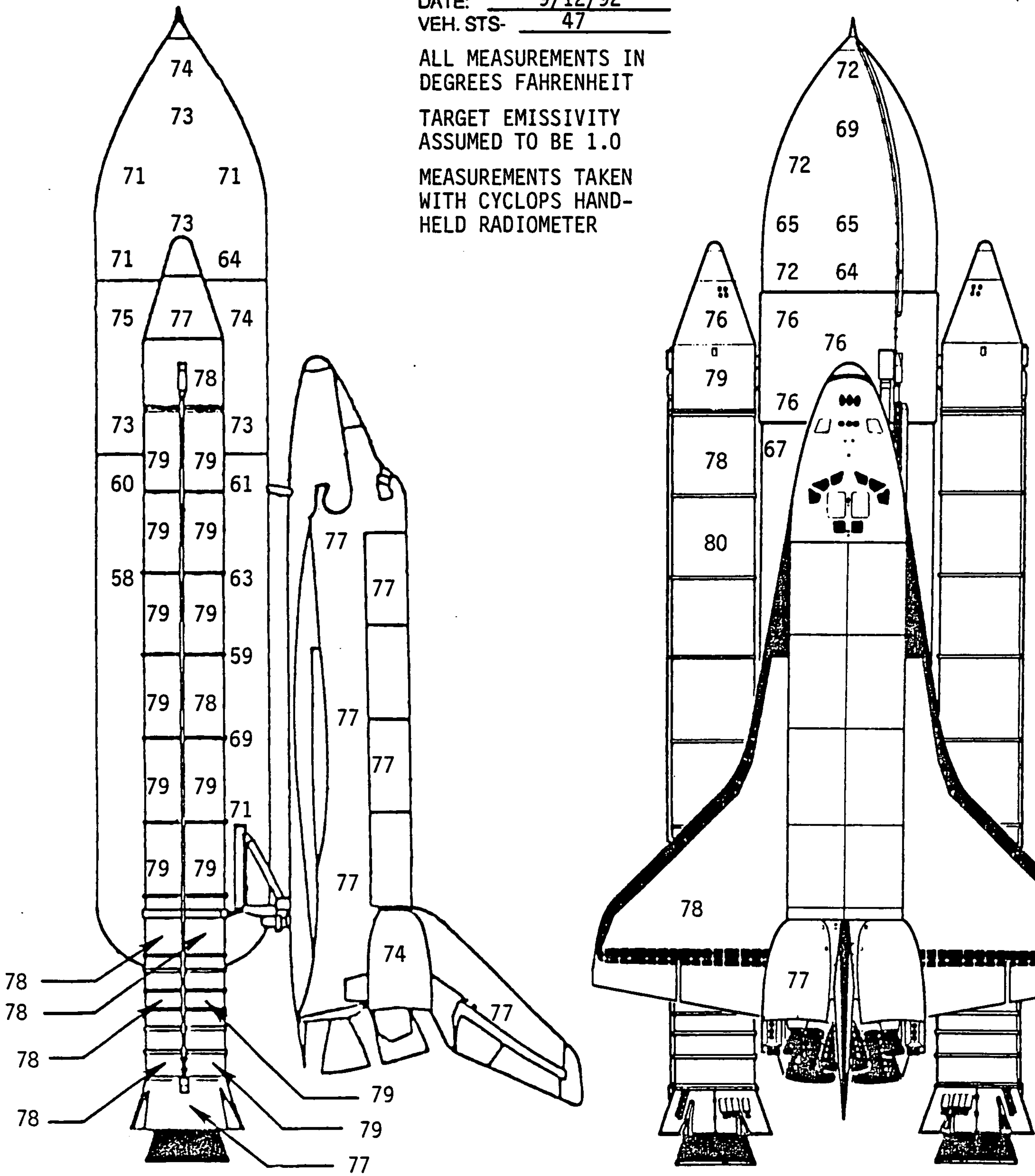
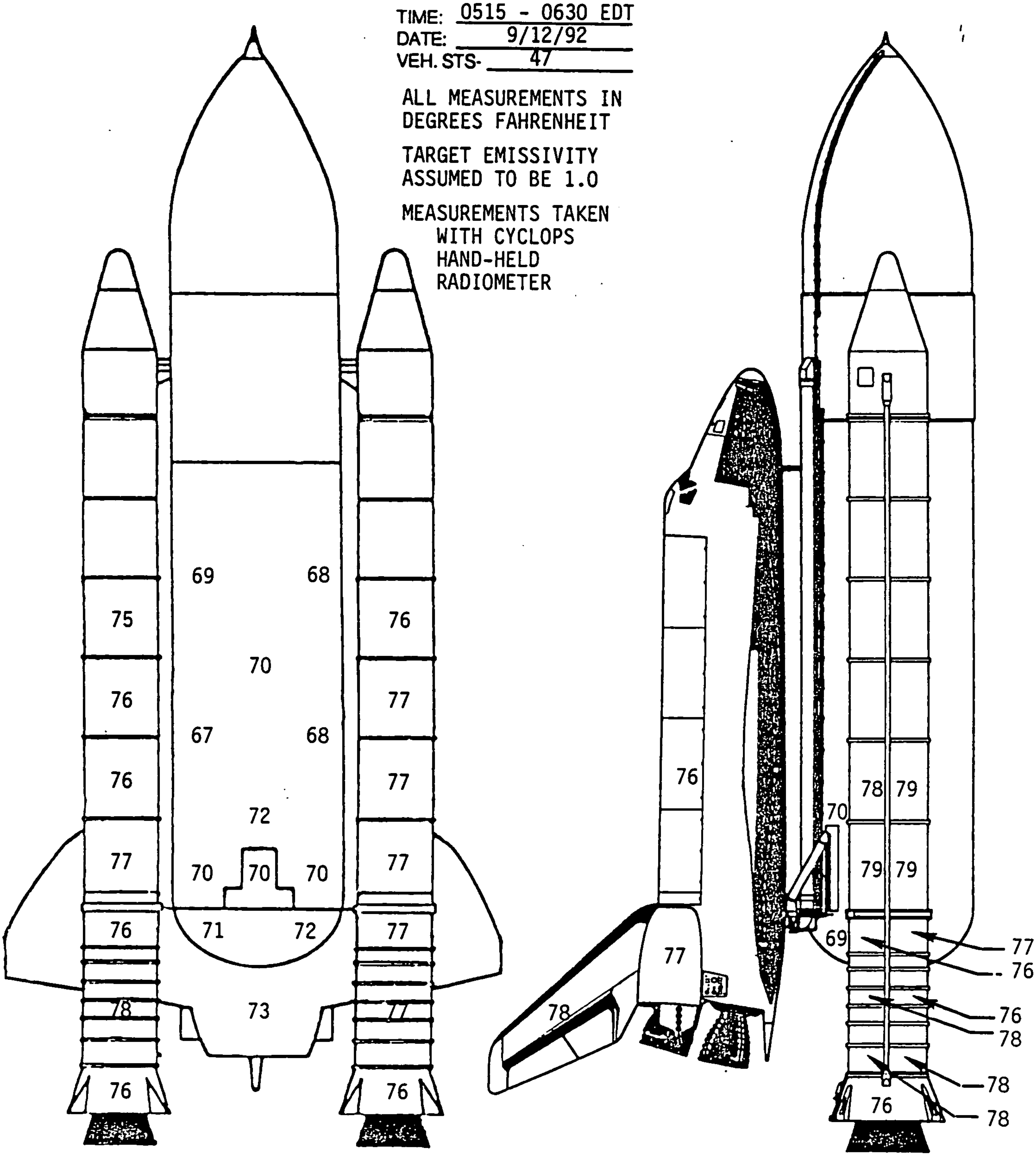


Figure 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**



3.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0215 to 1015 hours and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

There was light condensate, but no ice/frost accumulations, on the LO2 tank ogive and barrel sections. There were no TPS anomalies. The tumble valve cover was intact. The pressurization line and support ramps were in nominal configuration. The Cyclops radiometer measured surface temperatures that averaged 72 degrees F on the ogive and 69 degrees F on the barrel section. In comparison, SURFICE predicted temperatures of 64 degrees F on the ogive and 58 degrees F on the barrel.

Some light run-off condensate was present on the intertank TPS. Small frost spots appeared in the stringer valleys at both the LH2 and LO2 tank-to-intertank flanges. No unusual vapors or ice formations were present on the ET umbilical carrier plate. The Cyclops radiometer measured temperatures that averaged 75 degrees F.

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

There were no anomalies on the bipods, bipod jack pad closeouts, PAL ramp, cable tray/press line ice/frost ramps, longerons, thrust struts, manhole covers, or aft dome apex. Some ice/frost was present in the ET/SRB cable tray-to-upper strut fairing expansion joints. Ice/frost covered the lower EB fittings outboard to the strut pin hole with condensate on the rest of the fitting. The struts were dry. A 4-inch long by 1/4-inch wide crack was present in the forward surface TPS covering of the -Y vertical strut cable tray near the longeron closeout interface. The 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.

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

STS- 47	TEST S0007 LAUNCH	DATE: 11 September 1992	T-0 TIME: 10:23:00 DATE: 9-11-92	NASA KSC Ice/Frost/Debris Team

ORBITER	ET	SRB	MLP	PAD	LO2	LH2
105	45	BI-053	2	B	CHILLDOWN TIME: 02:12 SLOW FILL TIME: 02:38 FAST FILL TIME: 02:51 REPLENISH TIME: 04:55	CHILLDOWN TIME: 02:00 SLOW FILL TIME: 02:09 FAST FILL TIME: 02:56 REPLENISH TIME: 04:47

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
215	76.30	86.6	72.20	6	183	II	3.54	66.20	0.0028	-0.1670	II	3.54	61.07	0.0046	-0.1362	II	2.52	56.51	0.0045	-0.0917	II	2.28	55.40	0.0043	-0.0824
230	76.00	87.2	72.10	4	166	II	2.36	63.75	0.0026	-0.1200	II	2.36	56.93	0.0041	-0.0903	II	1.68	51.94	0.0039	-0.0789	II	1.52	51.94	0.0039	-0.0789
245	76.40	87.4	72.56	4	170	II	2.36	64.26	0.0027	-0.1224	II	2.36	57.47	0.0042	-0.0927	II	1.68	52.48	0.0040	-0.0814	II	1.52	52.48	0.0040	-0.0814
300	76.60	88.8	73.21	4	163	II	2.36	64.80	0.0027	-0.1251	II	2.36	58.06	0.0043	-0.0952	II	1.68	52.99	0.0041	-0.0840	II	1.52	53.00	0.0041	-0.0840
315	76.00	88.8	72.62	4	181	II	2.36	64.10	0.0027	-0.1217	II	2.36	57.30	0.0042	-0.0919	II	1.68	52.24	0.0040	-0.0804	II	1.52	52.24	0.0040	-0.0804
330	75.60	89.6	72.47	6	193	II	3.54	66.09	0.0030	-0.1664	II	3.54	60.95	0.0047	-0.1356	II	2.52	56.34	0.0046	-0.0910	II	2.28	55.22	0.0045	-0.0817
345	75.60	90.4	72.73	4	187	II	2.36	64.00	0.0028	-0.1212	II	2.36	57.18	0.0043	-0.0914	II	1.68	52.04	0.0041	-0.0795	II	1.52	52.04	0.0041	-0.0795
400	76.00	90.8	73.25	4	205	II	2.36	64.55	0.0028	-0.1239	II	2.36	57.77	0.0043	-0.0940	II	1.28	52.62	0.0041	-0.0823	II	5.44	64.39	0.0057	-0.2061
415	75.00	91.4	72.44	3	238	II	1.77	61.65	0.0026	-0.1076	II	1.77	53.48	0.0039	-0.0827	II	0.96	51.47	0.0041	-0.0769	II	4.08	60.95	0.0053	-0.1481
430	75.40	91.2	72.78	4	225	II	2.36	63.94	0.0028	-0.1209	II	2.36	57.11	0.0043	-0.0911	II	1.28	51.94	0.0041	-0.0791	II	5.44	63.79	0.0057	-0.2012
445	75.20	92.4	72.95	4	229	II	2.36	63.96	0.0029	-0.1211	II	2.36	57.13	0.0044	-0.0912	II	1.28	51.90	0.0041	-0.0790	II	5.44	63.84	0.0058	-0.2017
500	75.40	91.0	72.71	3	228	II	1.77	62.05	0.0026	-0.1096	II	1.77	53.90	0.0039	-0.0847	II	0.96	51.90	0.0041	-0.0789	II	4.08	61.34	0.0054	-0.1505
515	75.20	92.2	72.89	5	283	II	2.95	65.23	0.0030	-0.1443	II	2.95	59.38	0.0047	-0.1139	II	2.16	54.60	0.0045	-0.0788	II	6.05	64.58	0.0058	-0.2236
530	75.40	91.4	72.84	4	287	II	2.36	63.98	0.0028	-0.1211	II	2.36	57.15	0.0043	-0.0913	II	1.72	51.97	0.0041	-0.0798	II	4.84	62.91	0.0056	-0.1795
545	75.20	91.8	72.76	4	295	II	2.36	63.83	0.0029	-0.1204	II	2.36	56.99	0.0043	-0.0907	II	1.84	52.61	0.0042	-0.0784	II	4.92	62.90	0.0056	-0.1814
600	75.20	91.2	72.58	4	298	II	2.36	63.70	0.0028	-0.1198	II	2.36	56.86	0.0043	-0.0901	II	1.84	52.48	0.0042	-0.0779	II	4.92	62.78	0.0056	-0.1803
615	75.60	91.6	73.10	3	322	II	1.77	62.42	0.0026	-0.1114	II	1.77	54.29	0.0039	-0.0865	II	1.38	52.26	0.0041	-0.0806	II	3.69	60.79	0.0053	-0.1382
630	76.40	90.8	73.65	6	310	II	3.54	67.26	0.0031	-0.1740	II	3.54	62.19	0.0049	-0.1429	II	2.76	58.63	0.0049	-0.1063	II	7.38	66.98	0.0059	-0.2828
645	78.20	88.0	74.54	6	325	II	3.54	68.65	0.0029	-0.1831	II	3.54	63.68	0.0048	-0.1517	II	2.76	60.21	0.0049	-0.1139	II	7.38	68.27	0.0057	-0.2973
700	79.80	83.8	74.74	7	350	II	4.13	70.12	0.0027	-0.2129	II	4.13	65.76	0.0047	-0.1809	II	3.08	62.24	0.0048	-0.1318	II	6.93	68.62	0.0053	-0.2873
715	80.00	82.0	74.32	11	352	II	6.49	71.59	0.0024	-0.3068	II	6.49	68.56	0.0047	-0.2731	II	4.84	65.93	0.0050	-0.2020	II	10.89	70.69	0.0049	-0.4376
730	80.00	81.0	73.97	10	349	II	5.90	71.02	0.0023	-0.2806	II	5.90	67.73	0.0046	-0.2474	II	4.40	64.93	0.0049	-0.1824	II	9.90	70.01	0.0048	-0.3957
745	79.60	81.6	73.78	10	357	II	5.90	70.74	0.0024	-0.2779	II	5.90	67.44	0.0046	-0.2448	II	4.40	64.62	0.0049	-0.1802	II	9.90	69.73	0.0049	-0.3919
800	79.40	79.6	72.88	12	2	II	7.08	70.63	0.0021	-0.3159	II	7.08	67.76	0.0043	-0.2823	II	5.28	65.27	0.0048	-0.2086	II	11.88	69.80	0.0043	-0.4537
815	79.60	78.8	72.79	12	11	II	7.08	70.64	0.0020	-0.3159	II	7.08	67.77	0.0042	-0.2823	II	5.28	65.28	0.0047	-0.2086	II	11.88	69.80	0.0042	-0.4536
830	80.20	78.0	73.09	14	14	II	8.26	71.50	0.0017	-0.3659	II	8.26	69.01	0.0041	-0.3315	II	6.16	66.80	0.0046	-0.2462	II	13.86	70.80	0.0038	-0.5334
845	80.60	77.2	73.19	12	7	II	7.08	71.26	0.0018	-0.3230	II	7.08	68.43	0.0041	-0.2892	II	5.28	65.98	0.0046	-0.2143	II	11.88	70.42	0.0039	-0.4638
900	81.00	75.0	72.76	10	357	II	5.90	70.53	0.0017	-0.2753	II	5.90	67.22	0.0039	-0.2424	II	4.40	64.46	0.0044	-0.1789	II	9.90	69.46	0.0039	-0.3872
915	81.20	74.0	72.58	9	4	II	5.31	70.11	0.0017	-0.2517	II	5.31	66.51	0.0039	-0.2193	II	3.96	63.56	0.0042	-0.1614	II	8.91	68.89	0.0039	-0.3494
930	81.40	73.8	72.70	10	12	II	5.90	70.63	0.0016	-0.2762	II	5.90	67.33	0.0038	-0.2433	II	4.40	64.58	0.0043	-0.1797	II	9.90	69.54	0.0037	-0.3883
945	82.20	74.0	73.56	10	17	II	5.90	71.51	0.0016	-0.2851	II	5.90	68.26	0.0039	-0.2519	II	4.40	65.55	0.0043	-0.1866	II	9.90	70.44	0.0038	-0.4013
1000	82.00	72.4	72.75	11	16	II	6.49	71.17	0.0013	-0.3016	II	6.49	68.14	0.0036	-0.2683	II	4.84	65.59	0.0042	-0.1989	II	10.89	70.19	0.0033	-0.4285
1015	82.40	71.2	72.66	10	12	II	5.90	70.96	0.0013	-0.2793	II	5.90	67.68	0.0036	-0.2464	II	4.40	64.98	0.0041	-0.1824	II	9.90	69.85	0.0033	-0.3925
T-0	82.40	70.0	72.18	10	16	II	5.90	70.63	0.0012	-0.2760	II	5.90	67.34	0.0034	-0.2432	II	4.40	64.64	0.0039	-0.1799	II	9.90	69.51	0.0031	-0.3874
AVG.	78.01	84.26	73.01	7.06	N		4.16	67.28				4.16	62.17				3.03	58.57				6.83	64.22		

(shaded) Period of Ice Team Inspection

Figure 3. "SURFICE" Computer Predictions

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.

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

Amounts of ice/frost on the top, aft, and inboard sides of the LH2 ET/ORB umbilical purge barrier were typical; and less than usual on the outboard side. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Less than usual ice/frost had accumulated on the aft pyrotechnic canister bondline. Thin foam exists in this area due to an incorrect mold manufacture. The amount and location of the ice/frost was acceptable for launch per the NSTS-08303 criteria. A 3-inch ice/frost finger had formed on the cable tray vent hole. No ice/frost had formed on the 17-inch flapper valve actuator access port foam plug closeout. 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. There was no flight hardware or TPS contact.

The summary of Ice/Frost Team observations/anomalies consisted of five OTV recorded items:

Anomaly 001 documented ice/frost spots in the intertank -Z side string valleys at both LO2 tank and LH2 tank flange closeouts. The ice/frost spots were acceptable per NSTS-08303.

Anomaly 002 documented a 4-inch crack in the forward surface TPS covering of the -Y vertical strut cable tray near the longeron closeout interface. The crack exhibited no offset and were not filled with ice or frost. The condition was acceptable for launch per NSTS-08303 and CR S041254C.

Anomaly 003 documented two froth spots at the LH2 dome apex closeout bondline and the +Z manhole cover closeout. The conditions were acceptable for launch per the NSTS-08303 criteria.

Anomaly 004 (documentation only) recorded ice/frost formations on the LO2 umbilical purge vents and LH2 umbilical purge vents, purge barrier (baggie), and LH2 recirculation line bellows. The ice/frost formations were acceptable per NSTS-08303.

Anomaly 005 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets. These ice and frost formations were acceptable per NSTS-08303.

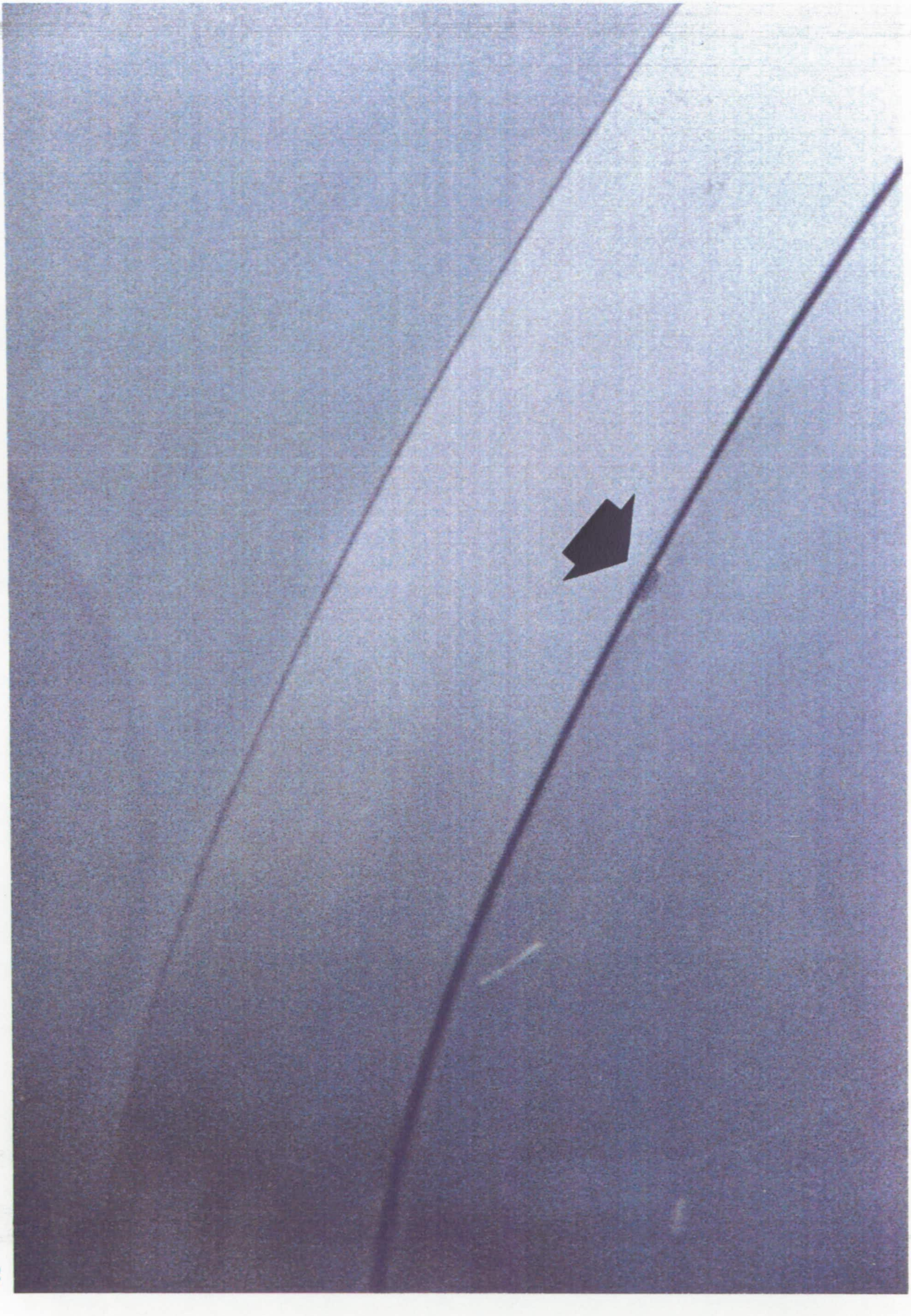
3.5 FACILITY

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. Five "Do Not Enter" safety signs with ropes were removed from the FSS-to-MLP zero level crossover (1), MLP south side (2), LH2 TSM door (1), and LO2 TSM door (1).

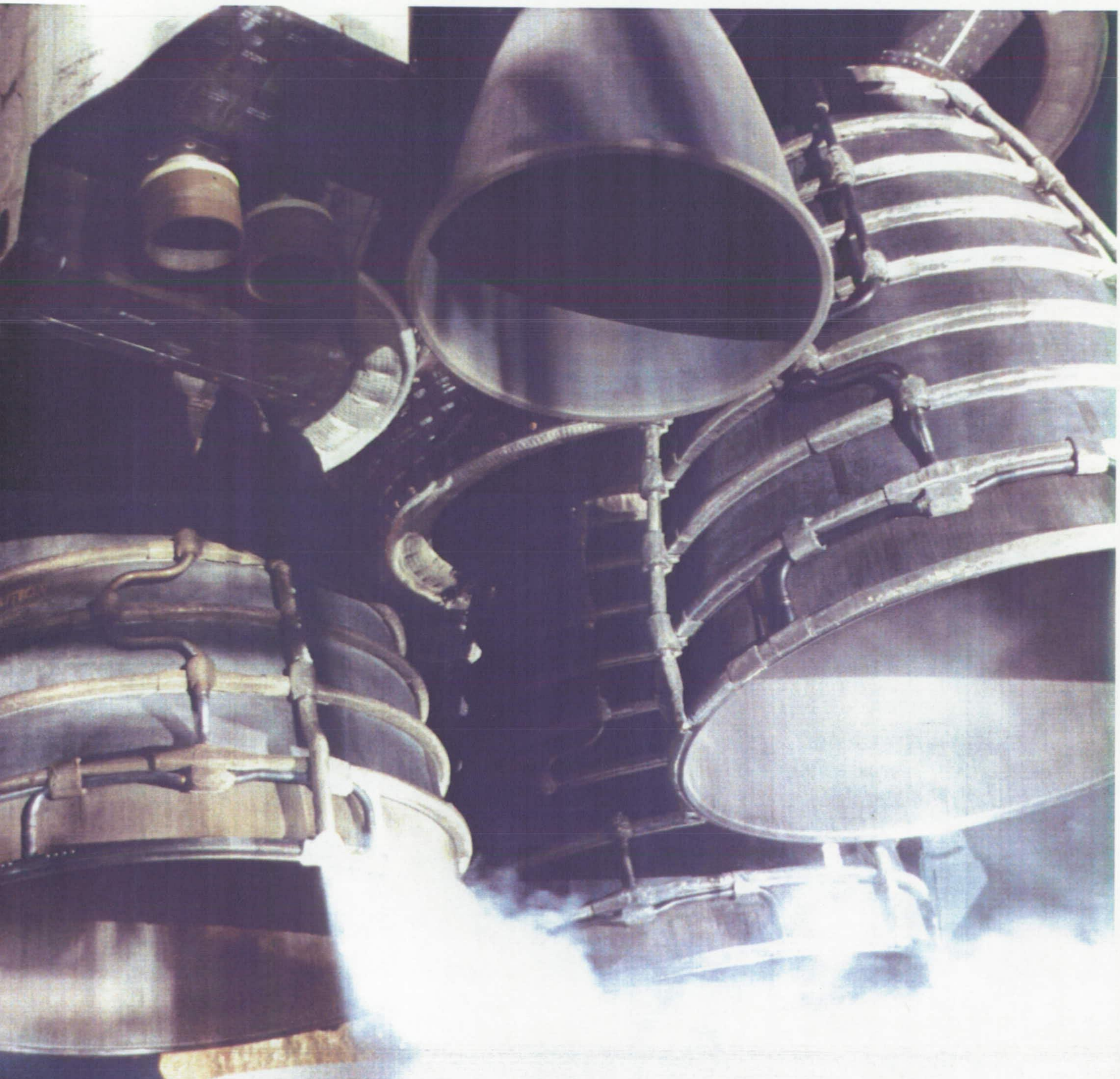
No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, though typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds. There was also no apparent leakage anywhere on the GH2 vent line or GUCP. The GH2 vent line modification prevented ice from forming, but some ice/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 had formed on the GOX vent ducts.

Light condensate, but no ice or frost accumulation, was present on the ET LO2 and LH2 tank TPS acreage

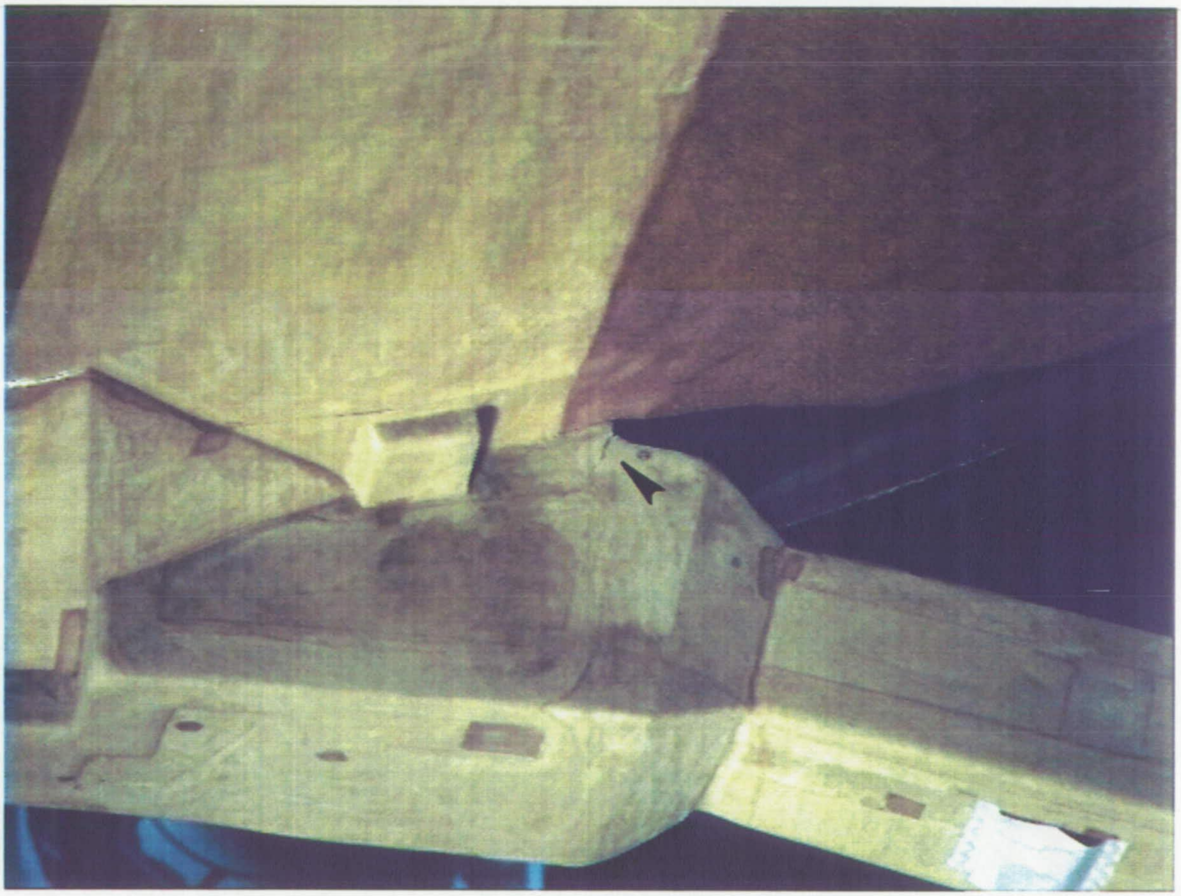


An IPR was taken against an apparent dent, or cavity, on the left wing RCC panel #9 adjacent to the T-seal. The IPR was dispositioned to fly as-is.



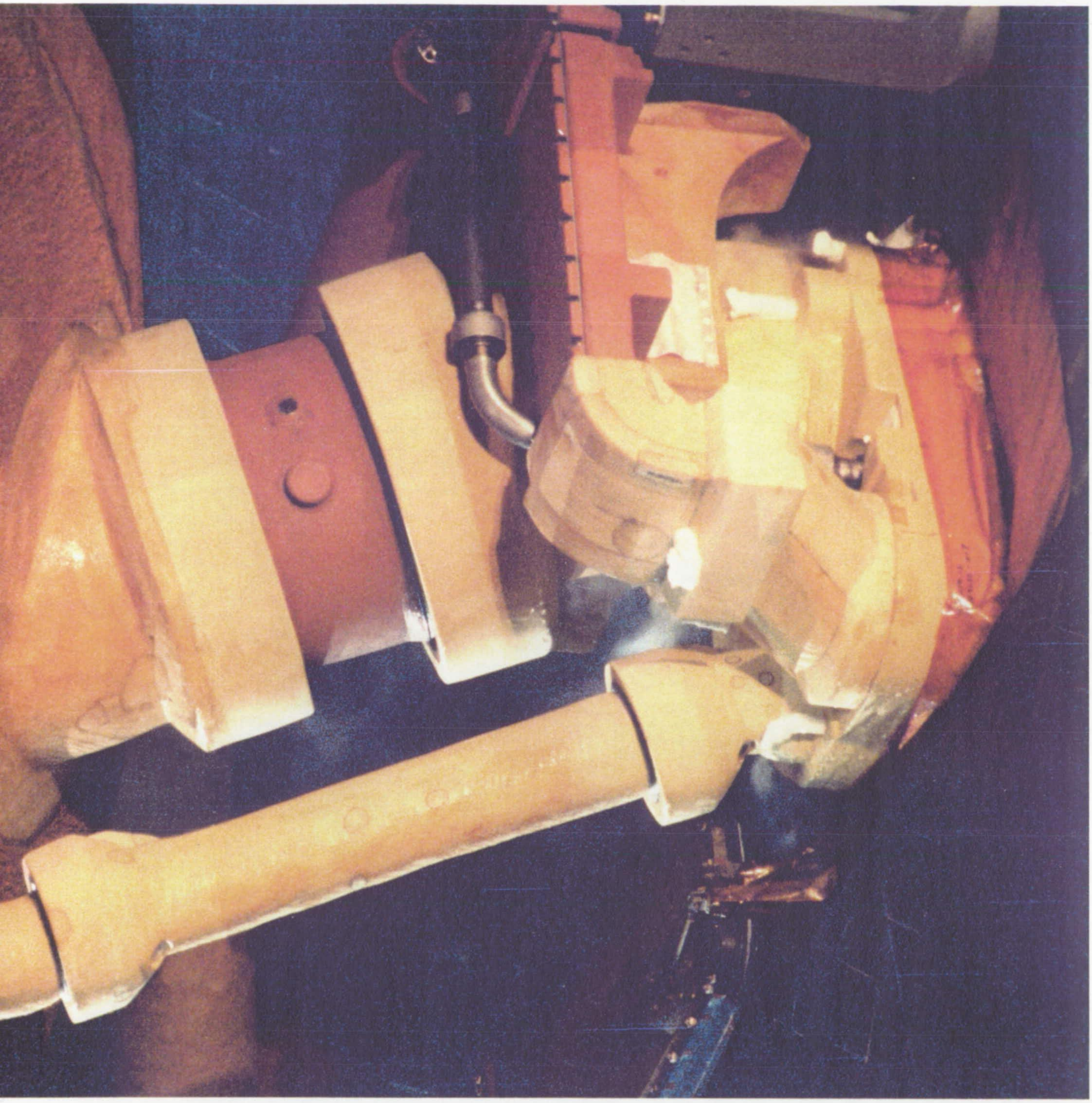
Less than usual ice/frost had formed at the SSME heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

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

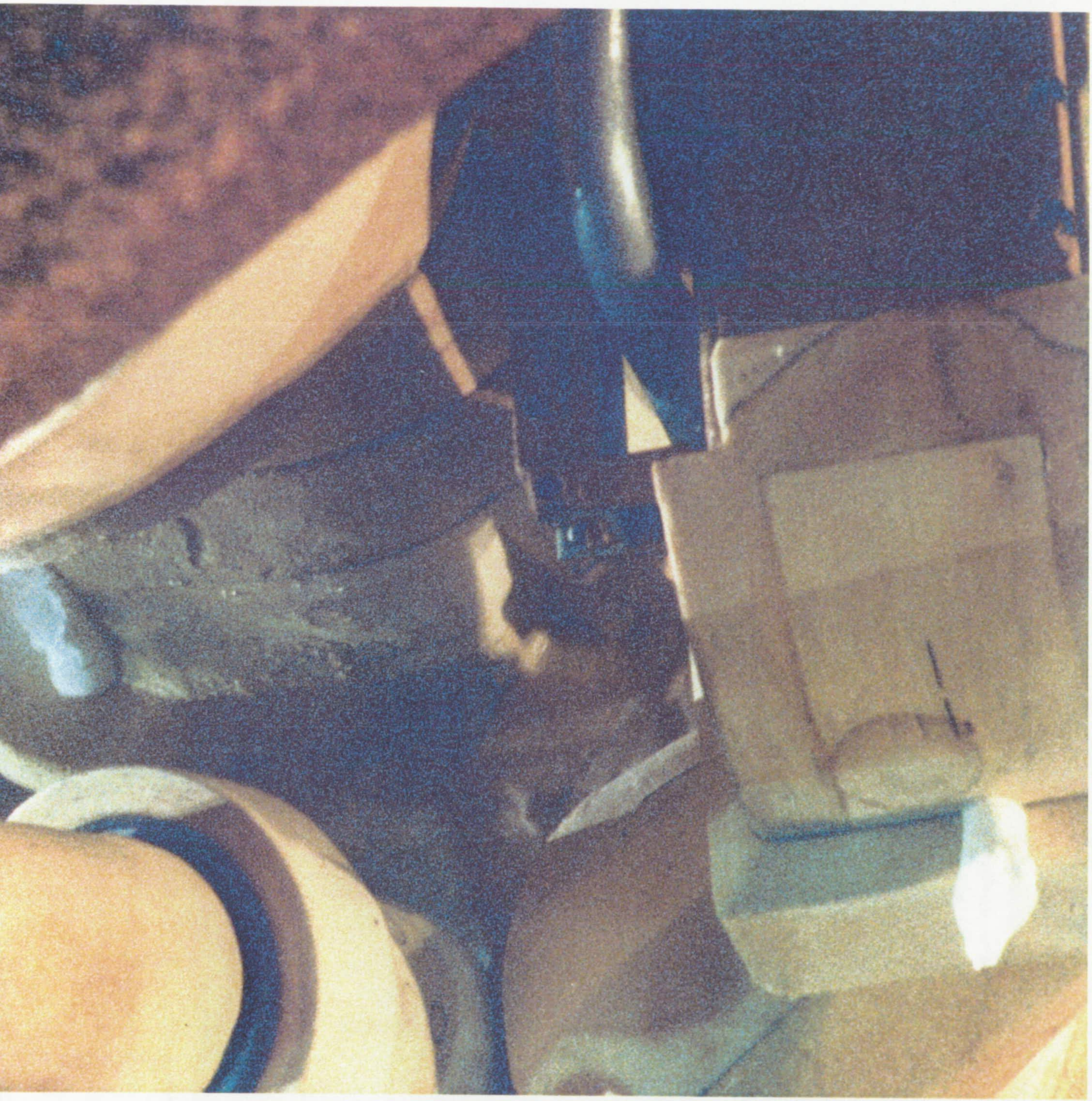


One crack, approximately 6 inches long, appeared in the LH (-Y) vertical strut/cable tray forward facing TPS covering near the longeron closeout interface. A stress relief cut in the TPS to allow for structural movement had been deleted by design. This condition was acceptable for flight per the NSTS-08303 criteria

Overall view of the LO2 ET/ORB umbilical. There were no TPS anomalies or unusual ice/frost formations.



Less than usual ice/frost had formed on the outboard and top sides of the LH2 ET/ORB umbilical/purge barrier. Typical amounts of ice had accumulated on the plate gap and pyrotechnic canister purge vents, and in the LH2 recirculation line bellows



Typical in size, ice/frost fingers had formed on the aft pyro canister purge vent and LH2 umbilical cable tray vent hole. No ice or frost had accumulated on the 17-inch flapper valve actuator access port foam plug closeout.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, pad surface, and pad acreage was conducted on 12 September 1992 from Launch + 1 to 3 hours. No flight hardware or TPS materials were found.

EPON shim material was intact and bonded to the shoes on all south holddown posts. There was no visual indication of a stud hang-up on any of the south holddown posts. No ordnance fragments were found in the south HDP stud holes. All of the north HDP doghouse blast covers were in the closed position and exhibited less than normal erosion. The SRB aft skirt purge lines were in place but slightly damaged. The SRB T-0 umbilicals exhibited minor damage.

The GOX vent arm, OAA, and TSM's showed the usual minor amount of damage. The GH2 vent line latched on the eighth tooth of the latching mechanism. There were no loose cables, but the north latch appeared to have contacted the north saddle stabilizer. The damage from this contact was minimal and has occurred on previous launches. The GH2 vent line showed typical signs of SRB plume impingement. The ET intertank access structure also sustained typical plume heating effects. The wire mesh on one of the hand rails had been pushed outward.

Damage to the facility appeared to be less than usual and included:

1. A 12" x 12" metal safety sign was found on the east side of the pad surface.

2. An FSS "175 foot level" sign was found on the grating of the FSS 175 foot level.

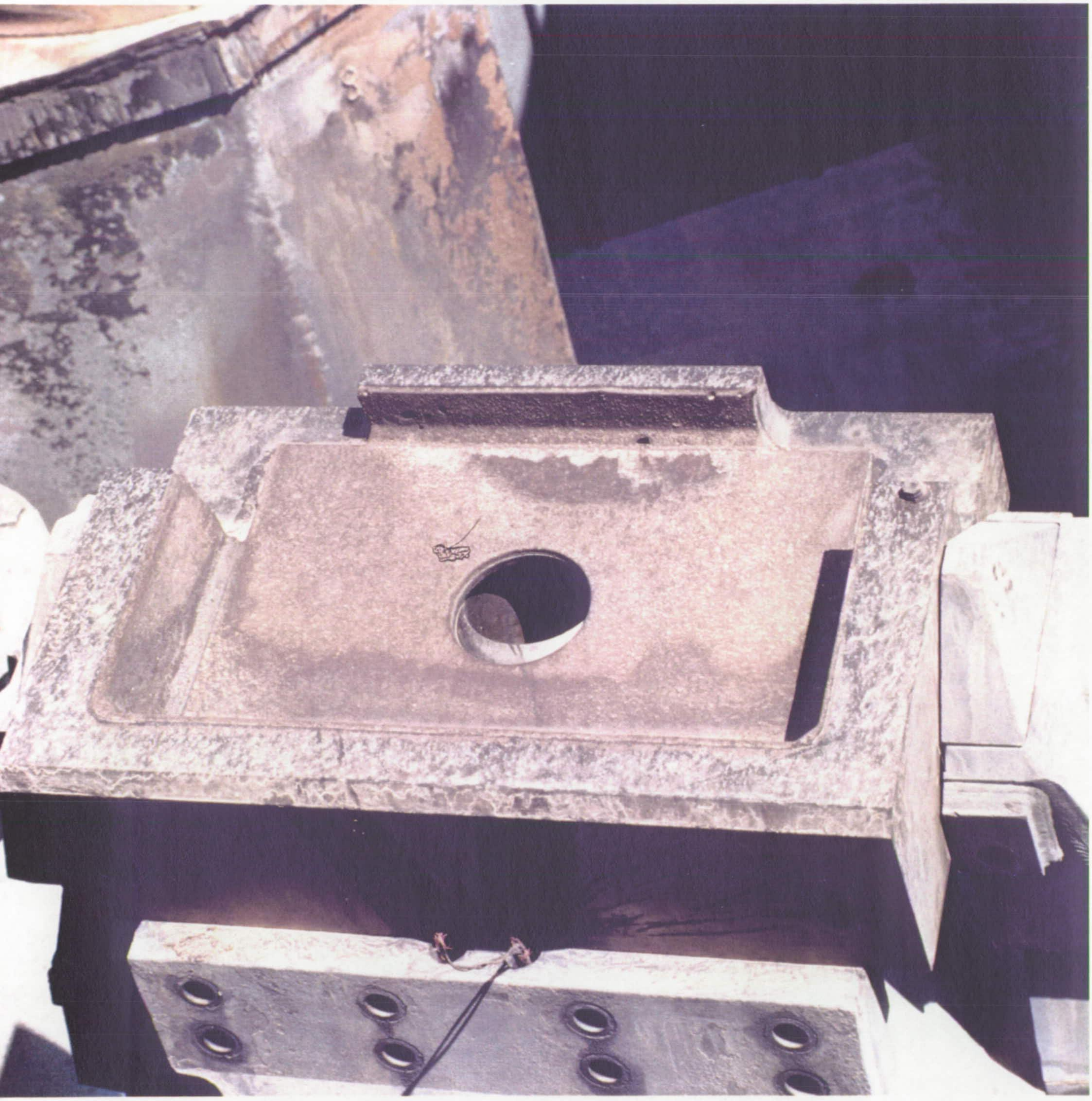
All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

An inspection of the beach from UCS-10 to Titan complex 40, the beach road, the railroad tracks, and the water areas around the pad and under the flight path was completed. No flight hardware was found.

MLP-2 was configured with overpressure sensors at the top of both TSM's, at the bottom of both SRB exhaust holes, and at the bottom of the SSME exhaust hole. All sensor readings were consistent with previous launches and within nominal limits with the exception of the sensor on top of the LH2 TSM. This sensor malfunctioned.

Patrick AFB and MILA radars were configured in a mode for increased sensitivity for the purpose of observing any debris falling from the vehicle during ascent but after SRB separation (due to the masking effect of the SRB exhaust plume). Most of the signal registrations were very weak and often barely detectable, which generally compares with the types of particles detected on previous Shuttle flights. A total of 73 particles were imaged in the T+138 to 326 second time period. Twenty-five of the particles were imaged by only one radar, 42 particles were imaged by two radars, and 6 particles were imaged by all three radars. The number and signal strength of the detected particles was comparable to the STS-46 mission.

Post launch pad inspection anomalies are listed in Section 9.



Plume erosion of the south SRB holddown posts was typical. EPON shim material was intact and bonded to the holddown post shoes.

All of the north holddown post doghouse blast covers were in the closed position and showed less than usual erosion

5.0 FILM REVIEW AND PROBLEM REPORTS

Post Launch Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. These anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 109 film and video data items, which included forty videos, forty-four 16mm films, twenty-two 35mm films, and three 70mm films, were reviewed starting on launch day.

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

SSME ignition, Mach diamond formation, and gimbal profile appeared normal. No discolorations or unusual streaks were visible in the Mach diamonds or exhaust plumes (E-2, 3, 19, 20, RSS STI, C/S-2 STI, OTV 151, 163, 170)).

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).

SSME ignition vibration/acoustics caused numerous pieces of ice/frost to fall from the LH2 and LO2 ET/Orbiter umbilicals. The 4-inch diameter ice formation on the LH2 ET/ORB umbilical cable tray vent hole fell off entirely during SSME ignition. No damage to Orbiter tiles was visible. There were no unusual vapors or cryogenic drips from the ET/ORB umbilicals during tanking, stable replenish, ignition, or liftoff (OTV 109, 150, 154, 163, 164, OTV 056, E-4). One piece of ice fell from the LO2 feedline upper bellows and passed in between the Orbiter and External Tank with no apparent contact (E-26).

SSME ignition vibration and acoustics caused the loss of tile surface coating material from one place on the body flap and one place on the LH RCS stinger aft surface (E-20). This film item also featured a burning piece of the magnesium button from the hydrogen burn ignitor at the LO2 TSM southwest corner. The magnesium did not contact any flight hardware and operation of the ignitor was nominal.

A small dark particle entered the field of view near the payload bay door centerline and fell aft along the vertical stabilizer without contacting flight hardware (E-76, frame 614).

Light frost was present in the ET GOX vent louvers. There was no TPS damage to the ET nose cone acreage, footprint, or fairing (OTV 160, 161). ET "twang" of approximately 34 inches was typical (E-79). The ET nosecone/pressure spike returned to the 12 inch mark at T-0.

There were no visual indications of stud hang-ups. No ordnance debris fell from any of the HDP DCS/stud holes. North holddown post doghouse blast covers closed normally.

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 163). GUCP disconnect from the External Tank was nominal (OTV 104). The GH2 vent line retracted and latched normally with no rebound. There was no excessive slack in the static retract lanyard (E-33, 41, 42, 48, 50).

Numerous debris particles, including pieces of SRB throat plug, were ejected upward out of the SRB exhaust holes. None of the objects contacted the vehicle, but some were drawn into the exhaust plumes by aspiration (E-1, 2, 25, 26). A large piece of SRB throat plug foam first appeared coming out of the exhaust hole between HDP #6 and #8, moved upward along side the LH SRB booster, and fell aft without contacting the Orbiter (E-3, 16, 18). Similarly, a large piece of SRB throat plug foam appeared in the field of view near the camera, but did not contact the vehicle (E-17). One small debris particle with a smoke trail moved upward into the field of view and eventually fell aft again without impacting the vehicle (E-26).

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

Numerous pieces of ice from the cryogenic lines on the north side of the MLP were lifted upward over the flame trench and the north MLP area by the SRB exhaust shock wave. None of the pieces impacted the vehicle (E-4, OTV 141, 160, 170, TV-4B, TV-7). Large white object over north area of the MLP was a piece of ice from the cryogenic line ejected upward by SRB plume shock wave (E-52, 76). A large piece of SRB sound suppression water trough material was visible above the LH2 TSM after the vehicle cleared the frame (E-76).

ET/ORB umbilical purge barrier (baggie) fell aft shortly after the roll maneuver at 14:23:16.698 GMT (E-54, 213).

Particles, most likely small pieces of SRB propellant, fell out of the LH SRB plume at 14:23:19.336 GMT (E-54).

A bird was first visible near the lower edge of the frame in film item E-59 falling along side the SRB plume at 14:23:32.105 GMT. Film item E-57 showed the bird was closer to the camera lens than the vehicle.

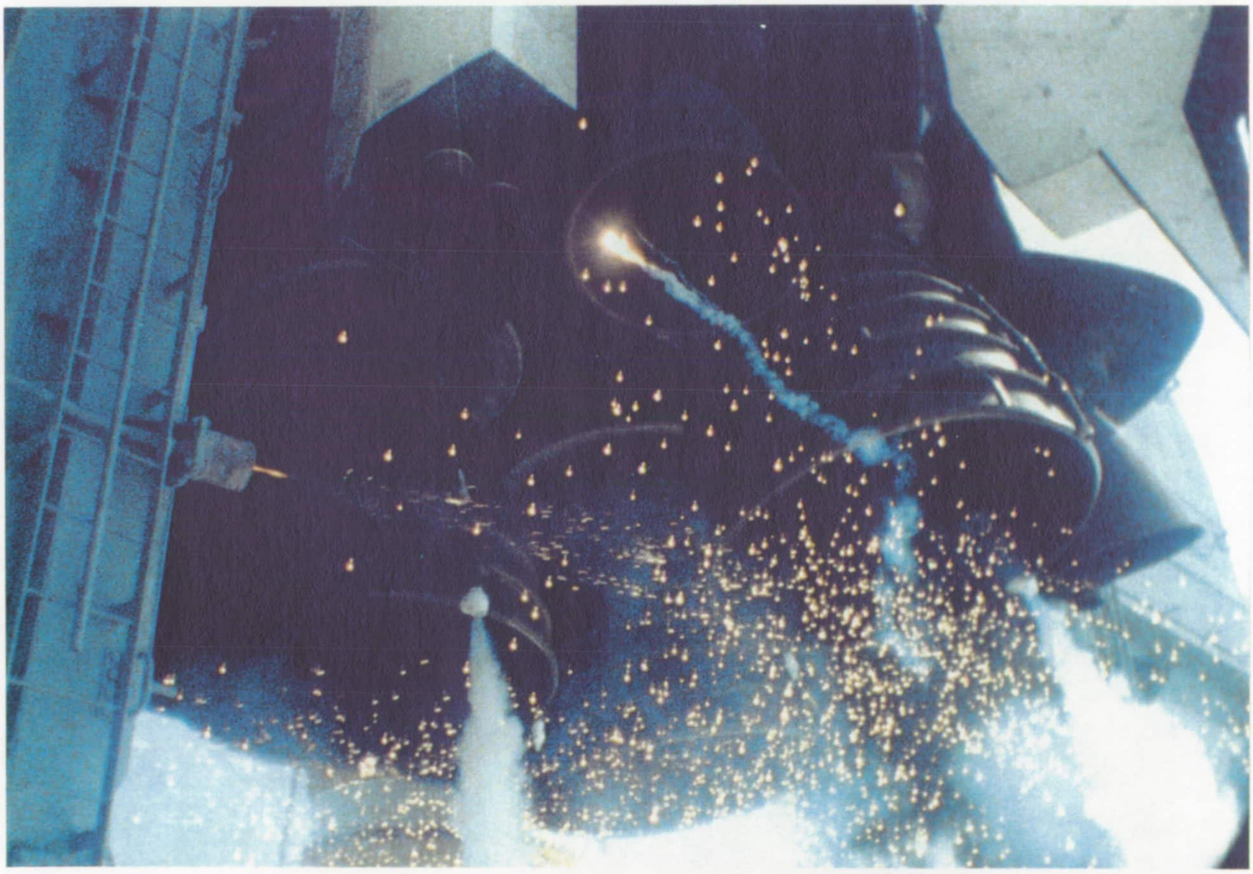
Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters and were pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings (E-213, 222).

Flashes occurred in the SSME plume during ascent at 14:23:19.857, 14:23:45.750, and 14:23:48.873 GMT (E-207, 222, 223, TV-4B).

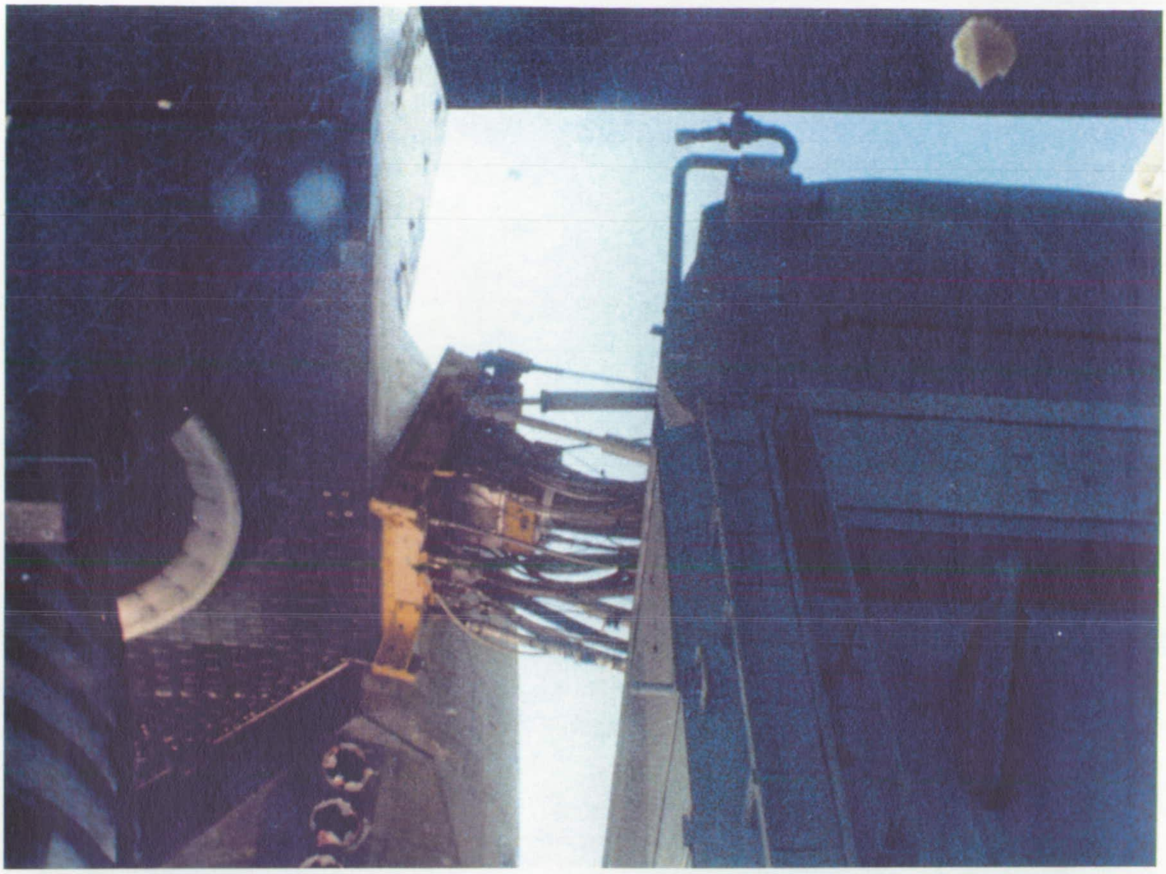
Movement of the body flap was similar to previous flights (E-207).

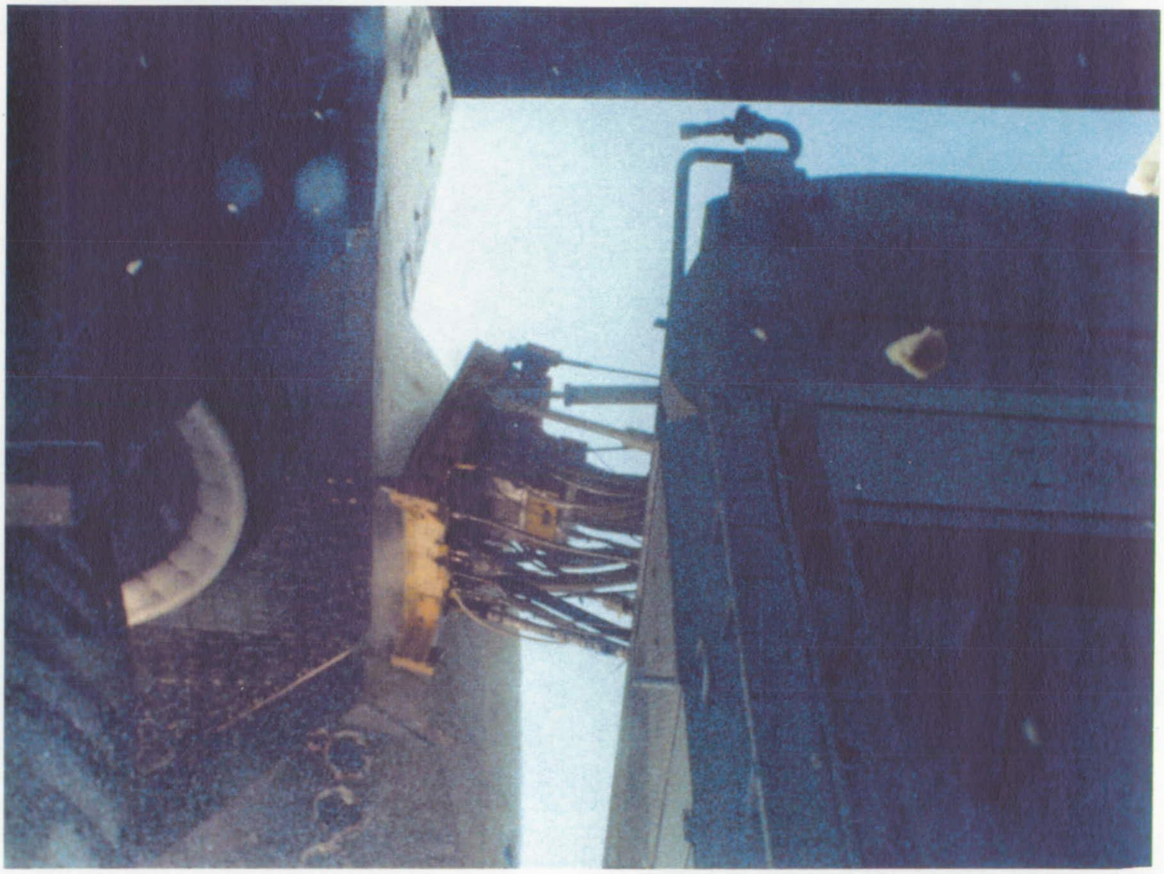
ET aft dome charring, exhaust plume recirculation, SRB plume tailoff, and SRB separation appeared normal (TV 13, 21B, E-207, 208, 223).

Frustum separation from the forward skirts and parachute deployment appeared normal. During reefing one parachute was late in opening but reach full reef position before nozzle severance (E-302). Nozzle severance debris, which was typical, caused some small tears/damage to the parachutes. Water splash down was not visible (E-301, 302).

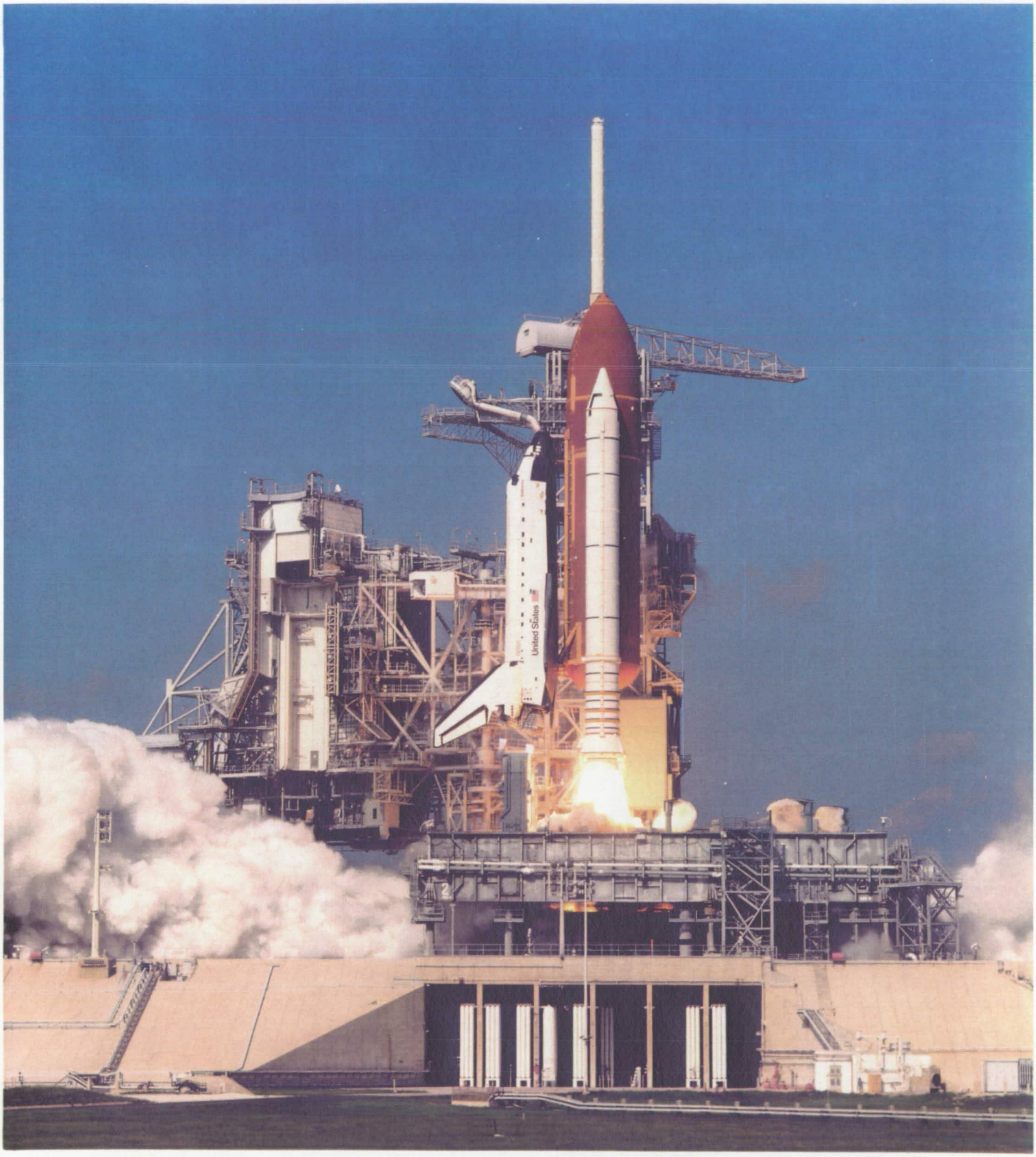


A piece of the magnesium button from the hydrogen burn ignitor on the LO2 TSM southwest corner did not contact any of the flight hardware. Although normally consumed before exiting the ignitor, the appearance of the magnesium was not anomalous.





Disconnect and separation of the LH2 T-0 umbilical from the Orbiter was nominal. A large piece of SRB throat plug material was ejected upward out of the exhaust hole, but did not contact any flight hardware.



All facility rainbirds operated properly. Light-colored objects over the north end of the MLP were pieces of SRB throat plug material and ice from the cryogenic lines ejected upward by the SRB plume/exhaust.

Clusters of particles falling aft of the Orbiter shortly after completion of the roll maneuver were pieces of the LH2 and LO2 ET/ORB umbilical purge barrier (baggie) material. Loss of the purge barrier during flight is a common and expected occurrence

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew and seventy 70mm still images were obtained of the ET after separation from the Orbiter. OV-105 was equipped to carry umbilical cameras: one 35mm and one 16mm with a 5mm lens. (The other 16mm camera with the 10mm lens had been deleted prior to launch due to an interference problem with the ET door latch drive shaft).

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. Separation of the -Y ET/SRB upper and diagonal struts appeared normal. No loss of TPS from the upper strut fairing was visible. No anomalies were observed on the LH SRB segment cases and joints, forward skirt, and frustum.

ET separation from the Orbiter appeared nominal. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, LO2 tank acreage, PAL ramps, RSS antennae, flight door, bipod jack pad closeouts and bipod ramps, aft hard point, and aft dome acreage. Frozen hydrogen, but no TPS or structural damage, was visible on the LH2 ET/ORB umbilical interface. Erosion and charring of TPS on the aft surfaces of the LH2 umbilical cable tray and the -Y vertical strut/cable tray was typical. Plume recirculation and aft dome heating caused the usual charring and "popcorning" of the NCFI foam.

A brass- or copper-colored object drifted away from the LH2 ET/ORB umbilical (16mm film, frame 4020). The origin of the object, a nut or spacer, has not been determined yet.

A piece of dark debris, possibly a small wire cutting, entered the FOV (16mm film, frame 4249) from the inboard side of the vehicle and drifted upward out of sight. It reappeared at frame 4855 drifting downward (aft). The object was inside the Orbiter aft compartment between the camera lens and the window pane. The object has crossed the near side (inside) of the window black retaining ring as it entered the field of view. The object was later observed to bounce against the glass window twice while crossing the field of view.

The LO2 ET/ORB umbilical 2-inch press line red seal/white RTV looked "blown out" on the outboard side but was actually the result of the overpressure test/closeout work at the pad. In addition, a layer of TPS had rolled back on the forward surface of the umbilical and possible foam damage appeared on the inboard side of the umbilical. Foam was also lost from the vertical and horizontal sections of the umbilical cable tray.

Erosion and "popcorning" on the LO2 feedline flange closeouts, +Y thrust strut flange closeout, and 5 press line ramps (small pieces) was typical.

An acreage divot to substrate was visible below the LH2 tank PAL ramp adjacent to the cable tray (XT-1528).

Four 6-8 inch divots were clustered in the intertank-to-LH2 tank flange closeout at the +Y+Z corner of the +Y thrust panel.

Two 8-inch divots in the intertank-to-LH2 tank flange closeout and one 8-inch divot at the -Y+Z corner of the -Y thrust panel were clustered together.

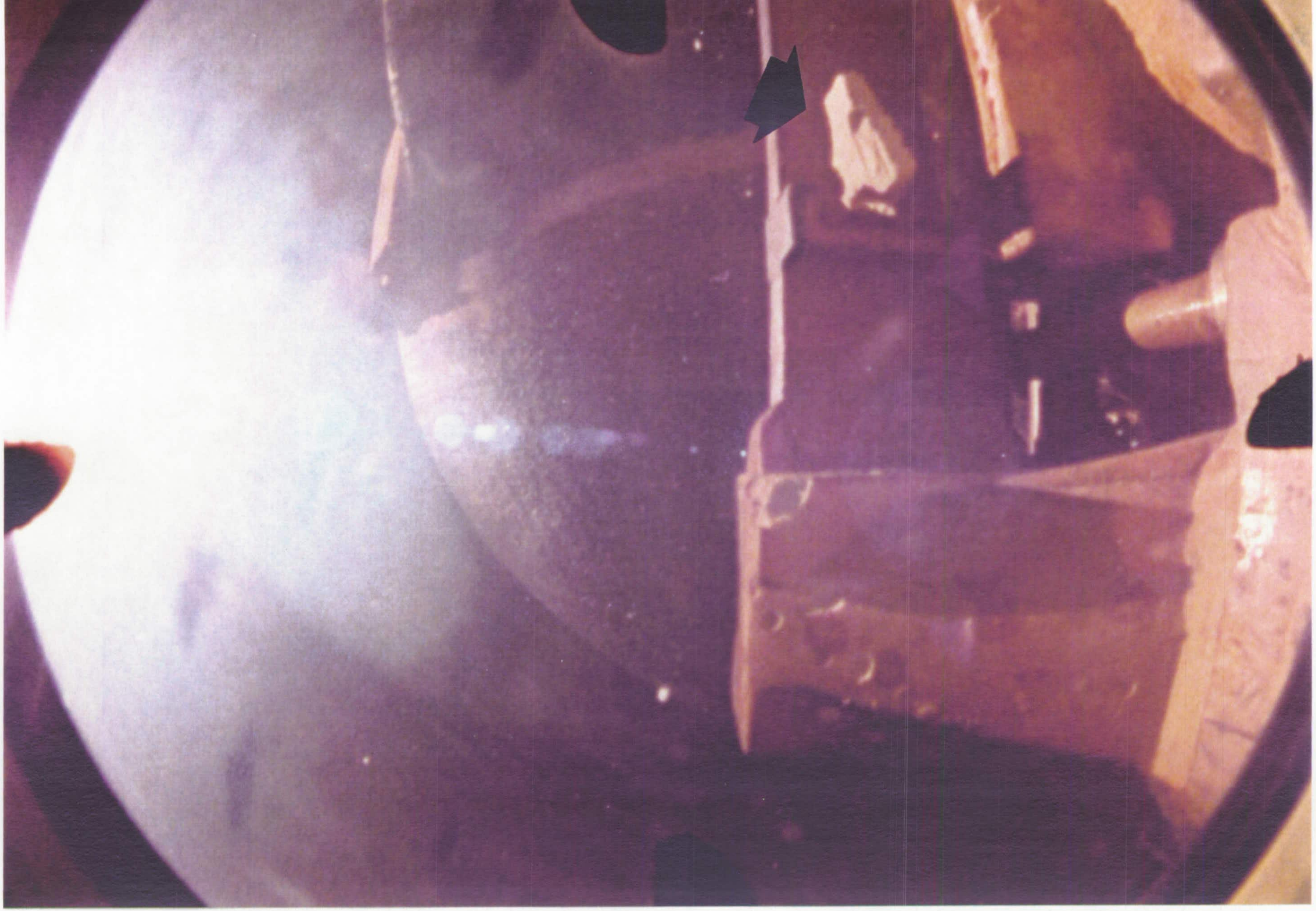
A 10-12 inch divot was visible in the LH2 flange closeout in -Y+Z quadrant.

A 14-16 inch divot occurred in the intertank acreage between the bipods just forward of the LH2 tank-to-intertank flange closeout (IFA candidate). A large piece of foam had drifted aft (downward) into the field of view of the 16mm camera. The piece of foam seemed to exhibit stringer-sized indentations on one side and may indicate the piece of foam had originated from the intertank divot.

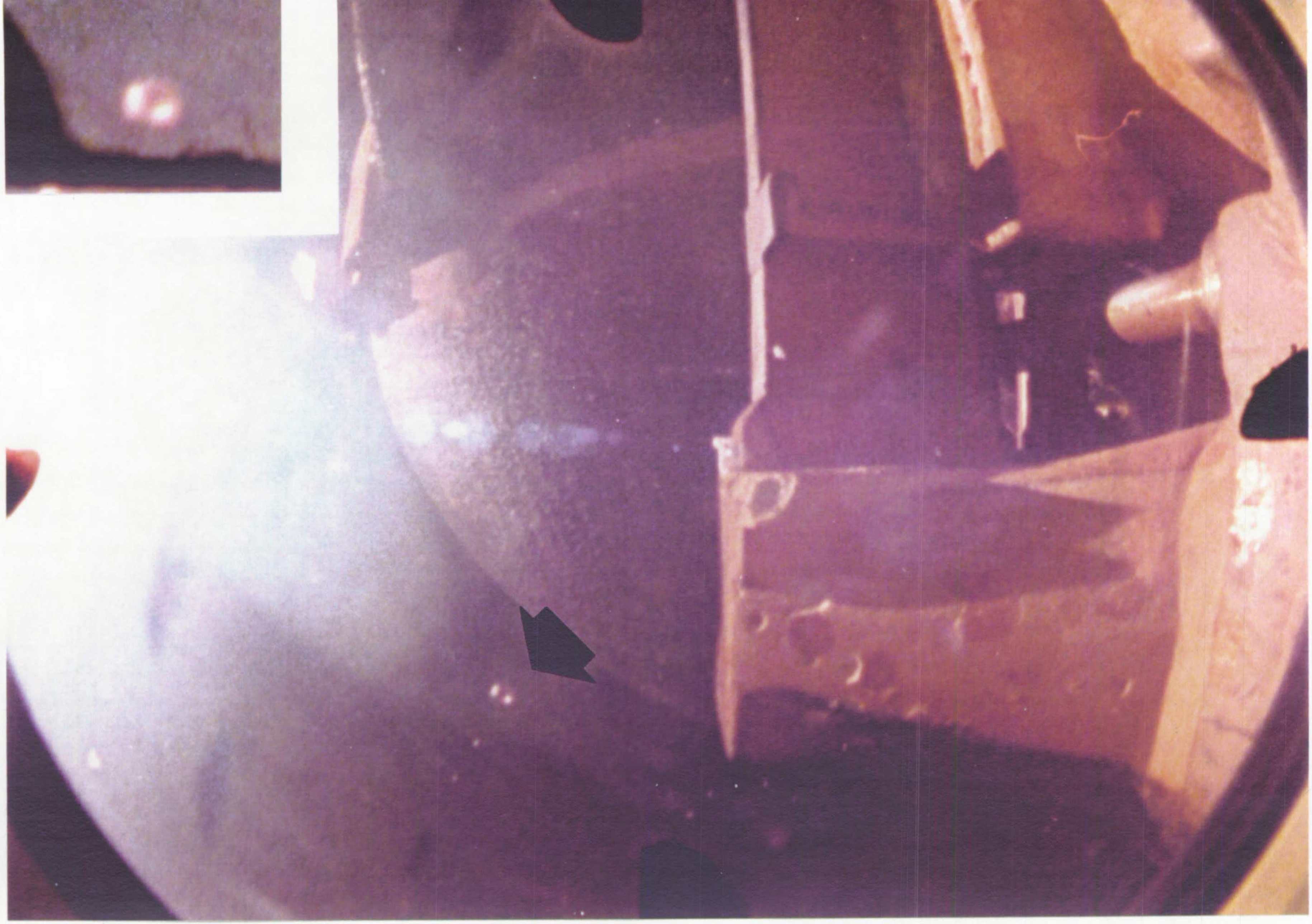
A 4-6 inch divot was present in the LH2 tank acreage just below the LH (-Y) bipod spindle/flange.

A 6-8 inch divot was present behind the LH bipod just forward of the jack pad closeout. The divot is located in the LH2 tank-to-intertank flange closeout.

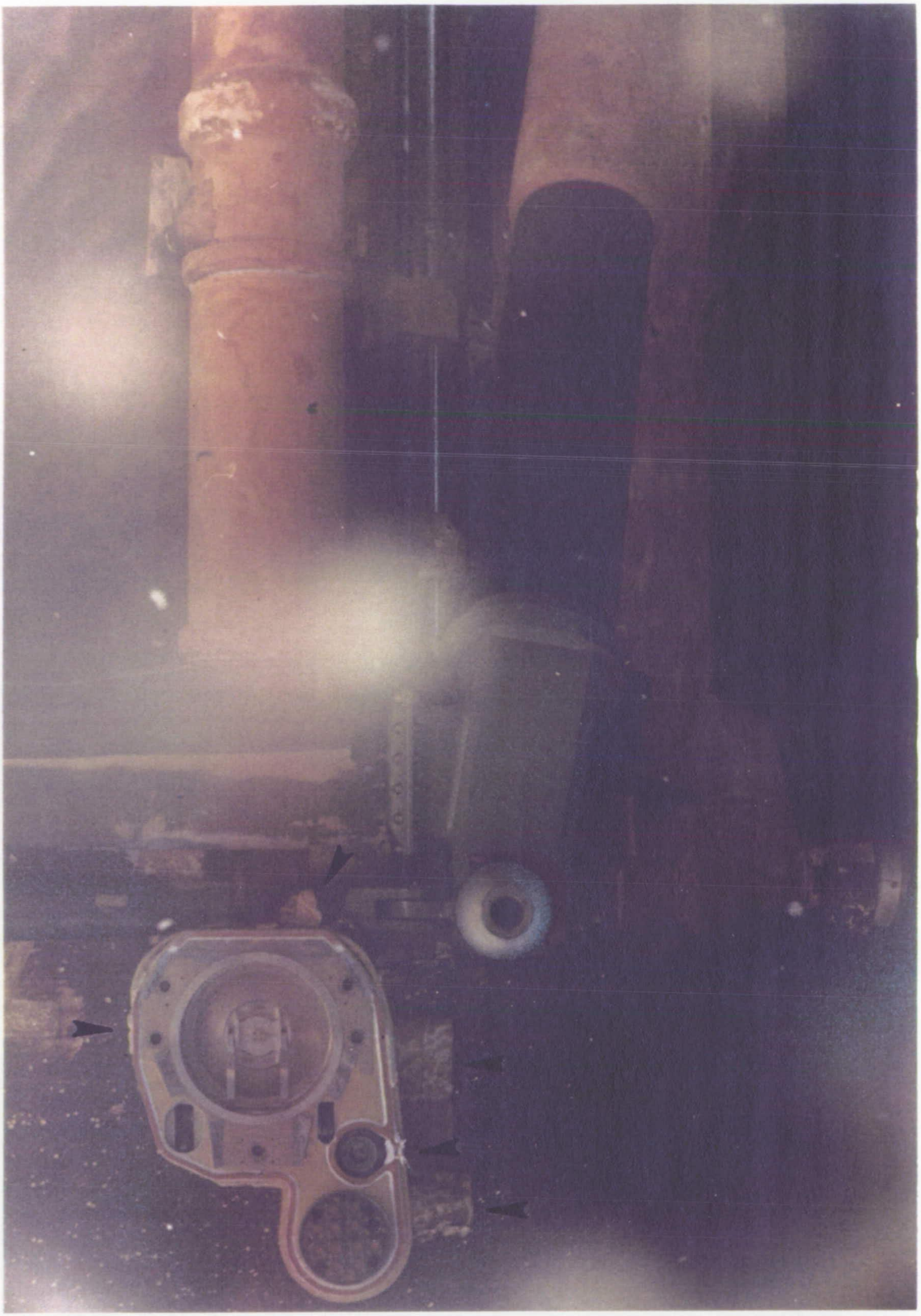
Wide angle view from a camera in the LH2 ET/ORB umbilical showed nominal separation of the LH SRB from the External Tank. Note erosion/loss of material from the TPS on the vertical strut/cable tray aft surface and the umbilical cable tray outboard side.



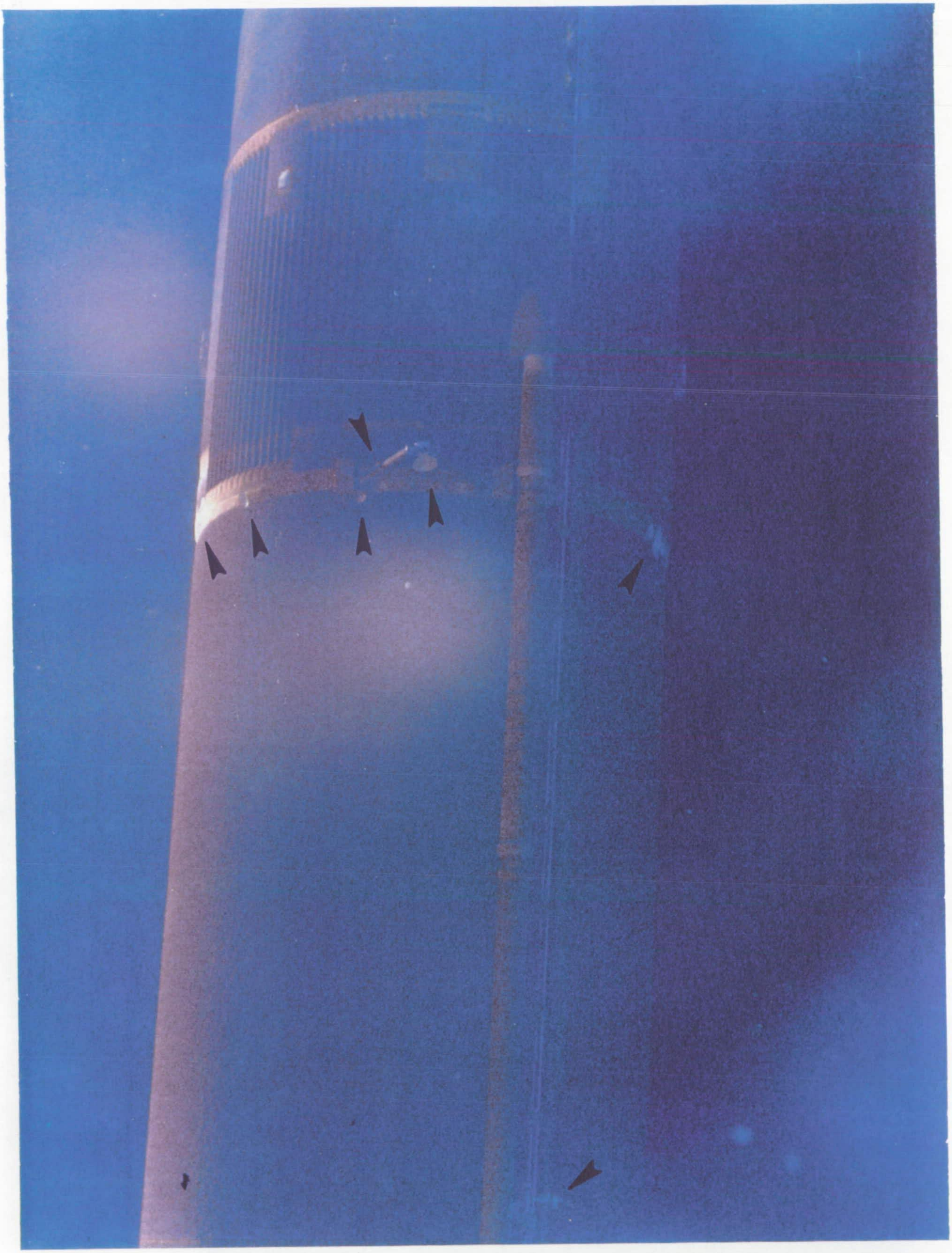
Piece of TPS falling aft past the LH2 ET/ORB umbilical cable tray vertical section (arrow) features an indentation similar to an intertank stringer and may indicate the foam piece originated from the intertank acreage divot.



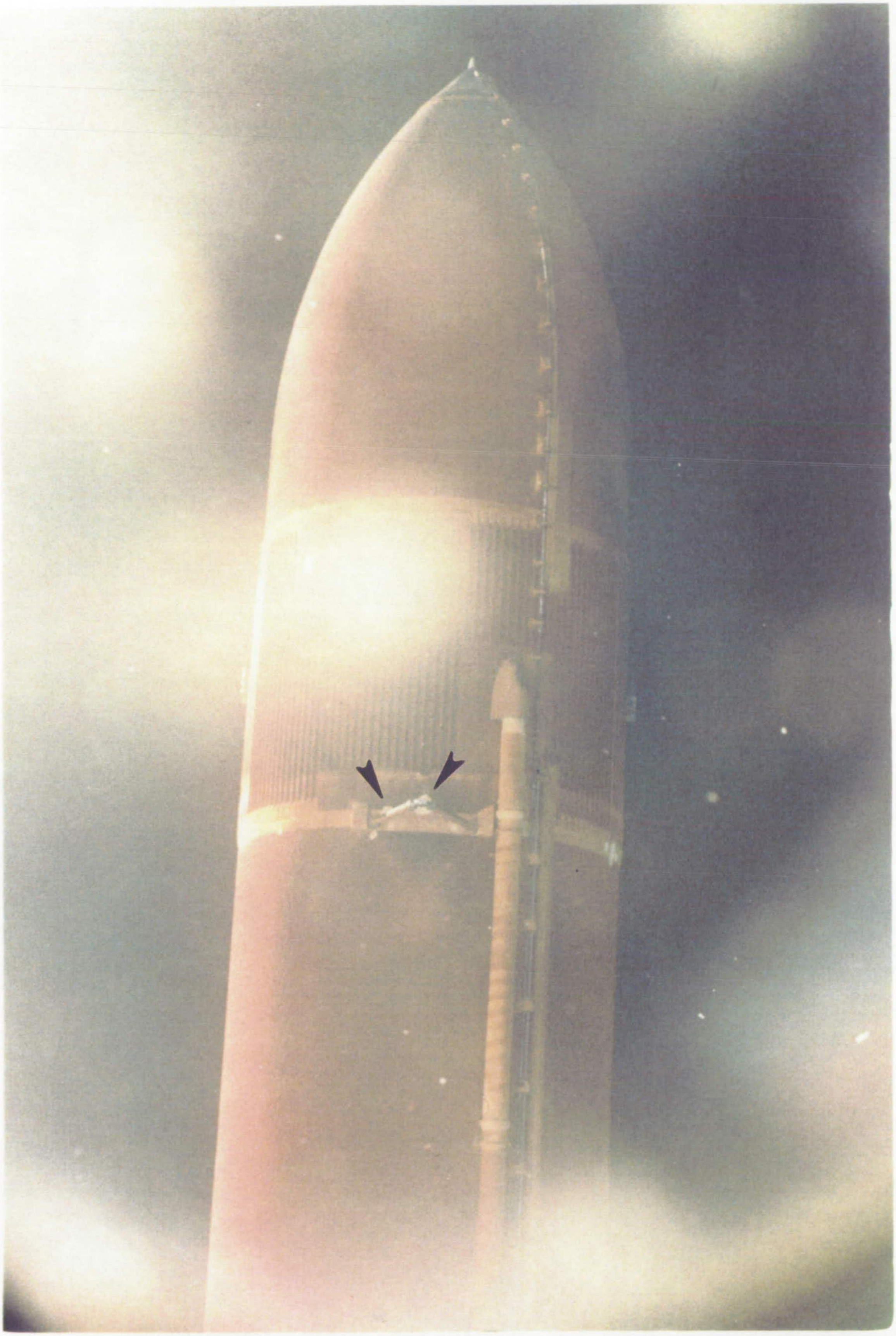
A brass- or copper-colored object drifted away from the LH2 ET/ORB umbilical area during separation of the External Tank from the Orbiter. The identification and origin of the object, believed to be a nut or spacer (inset), has not been determined yet.



View from the LO2 ET/ORB umbilical separation camera showed a layer of TPS had rolled back on the forward surface of the umbilical and possible foam damage appeared on the inboard side. Foam was also lost from the vertical and horizontal sections of the umbilical cable tray. The 2-inch press line red seal/white RTV looked "blown out", but was actually the result of the overpressure test/closeout work at the pad.



Divots were visible in the LH2 tank acreage aft of the PAL ramp and LH bipod spindle, in the LH2 tank-to-intertank flange closeout, and in the intertank acreage TPS between the bipods.



An IFA was taken against the 14-16 inch diameter divot in the intertank acreage TPS between the bipods. No anomalies/divots were apparent on the LO2 tank or nosecone.

Flight crew hand-held photography of the External Tank revealed no anomalies on the LO2 or LH2 tank TPS acreage. The BSM burn scar and aft dome charring were typical. Two divots occurred in the LH2 tank-to-intertank flange closeout.

ORIGINAL PAGE
COLOR PHOTOGRAPH

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 25 film and video data items, which included eight videos, eight 16mm high speed films, and nine 35mm large format films, were reviewed.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. The landing gear extended properly. Left and right main landing gear touchdown was almost simultaneous.

Drag chute was deployed at approximately 175 knots (indicated) just before nose gear rotation. Deployment of the drag chute itself appeared nominal. However, three tiles on the vertical stabilizer "stinger" were damaged by contact with the chute risers. A 2-4 knot crosswind blew the drag chute eastward relative to the Orbiter and caused the nose to yaw left (westward). Active steering and braking was required to bring the vehicle back on runway centerline.

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

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 14 September 1992 from 1030 to 1230 hours. From a debris standpoint, both SRB's were in excellent condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had 42 MSA-2 debonds over fasteners and one 2-inch diameter area of missing TPS on the -Y axis at the 275 ring frame. Minor localized blistering of the Hypalon paint had occurred predominantly along the 395 ring (Figure 4). All BSM aero heatshield covers were locked in the fully opened position though the left two cover attach rings had been bent by parachute riser entanglement.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. However, the +Z antenna phenolic plate was delaminated. Minor blistering of the Hypalon paint occurred on the systems tunnel cover and forward ET/SRB attach point (Figure 5). No pins were missing from the frustum severance ring. The forward separation bolt and electrical cables appeared to have separated cleanly.

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

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The upper strut fairing was missing a 4" x 3/4" area of K5NA and the substrate was charred. All three aft booster stiffener rings sustained water impact damage. 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 had been eliminated. RTV-133 replaced the K5NA over the forward fasteners. Three divots, measuring 3" in diameter, 4"x2", and 4"x2", had occurred on the aft skirt TPS (Figure 6).

All Debris Containment System (DCS) plungers were seated properly. This was the tenth flight utilizing the optimized link. Pieces of EPON shim were missing from HDP #4 (3-inch diameter) and HDP #3 (2-inch diameter). The material was lost prior to water impact (sooted/charred substrate).

Figure 4. **RIGHT SRB FRUSTUM**

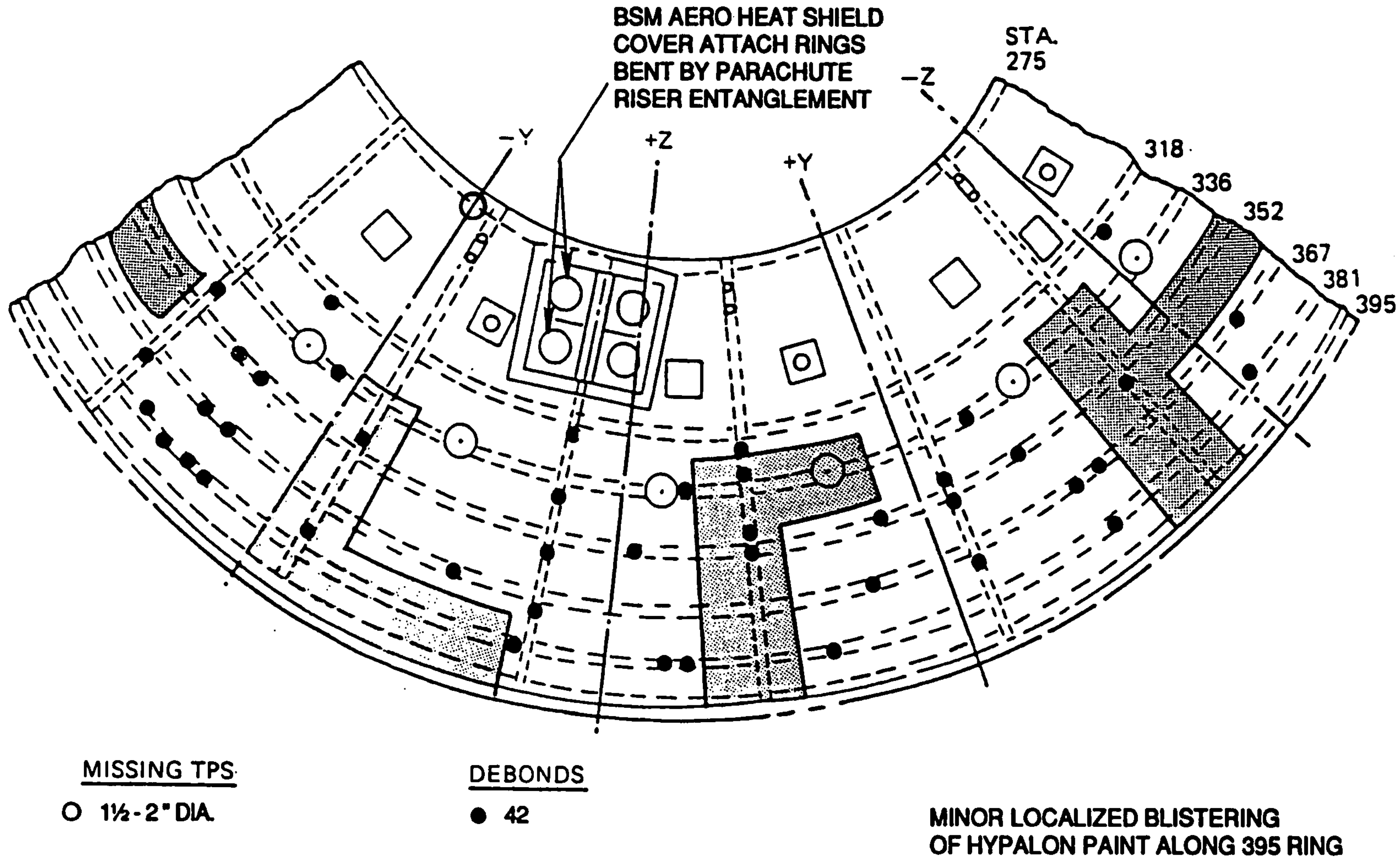


Figure 5. **RIGHT SRB FWD SKIRT**

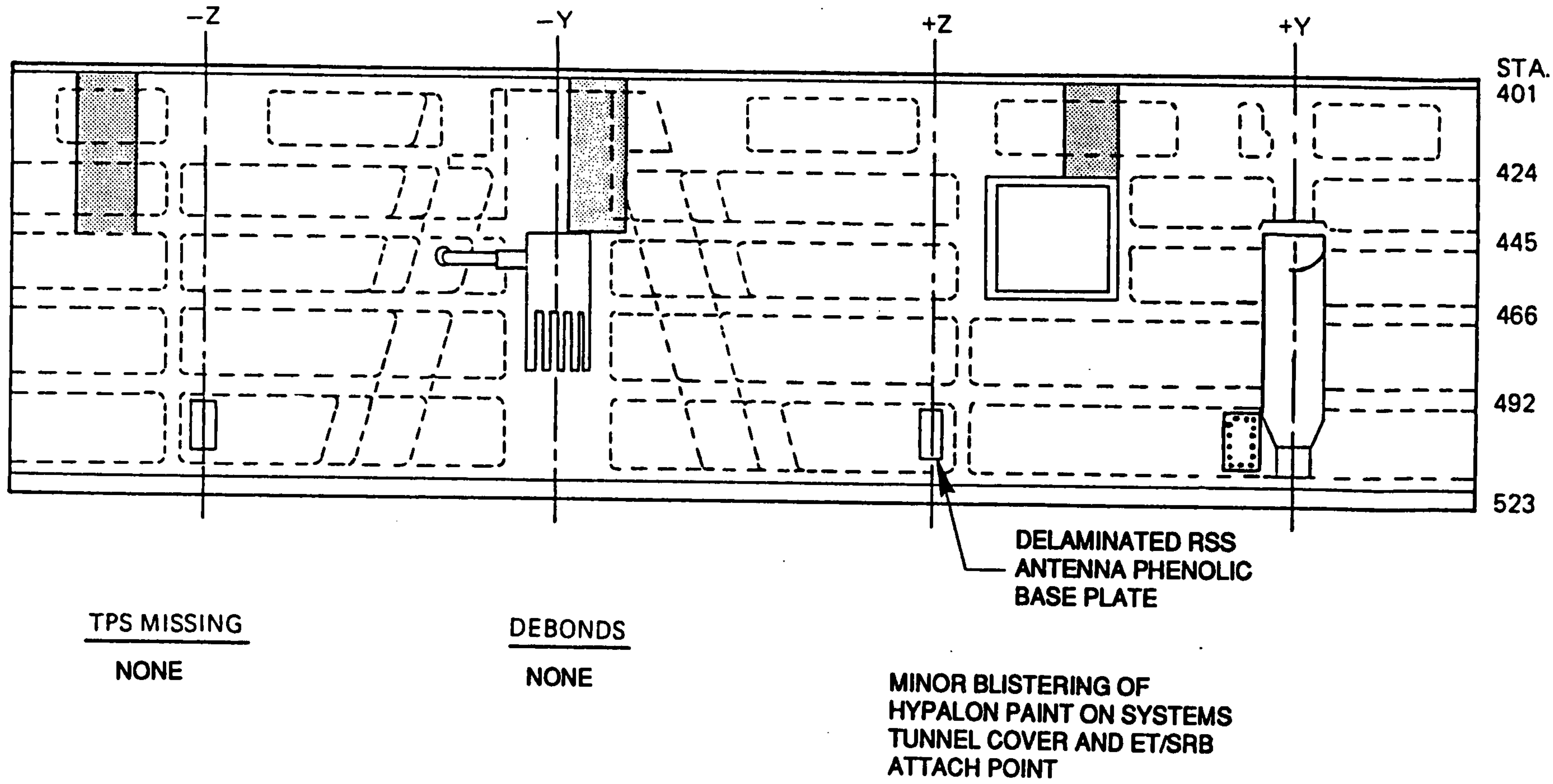
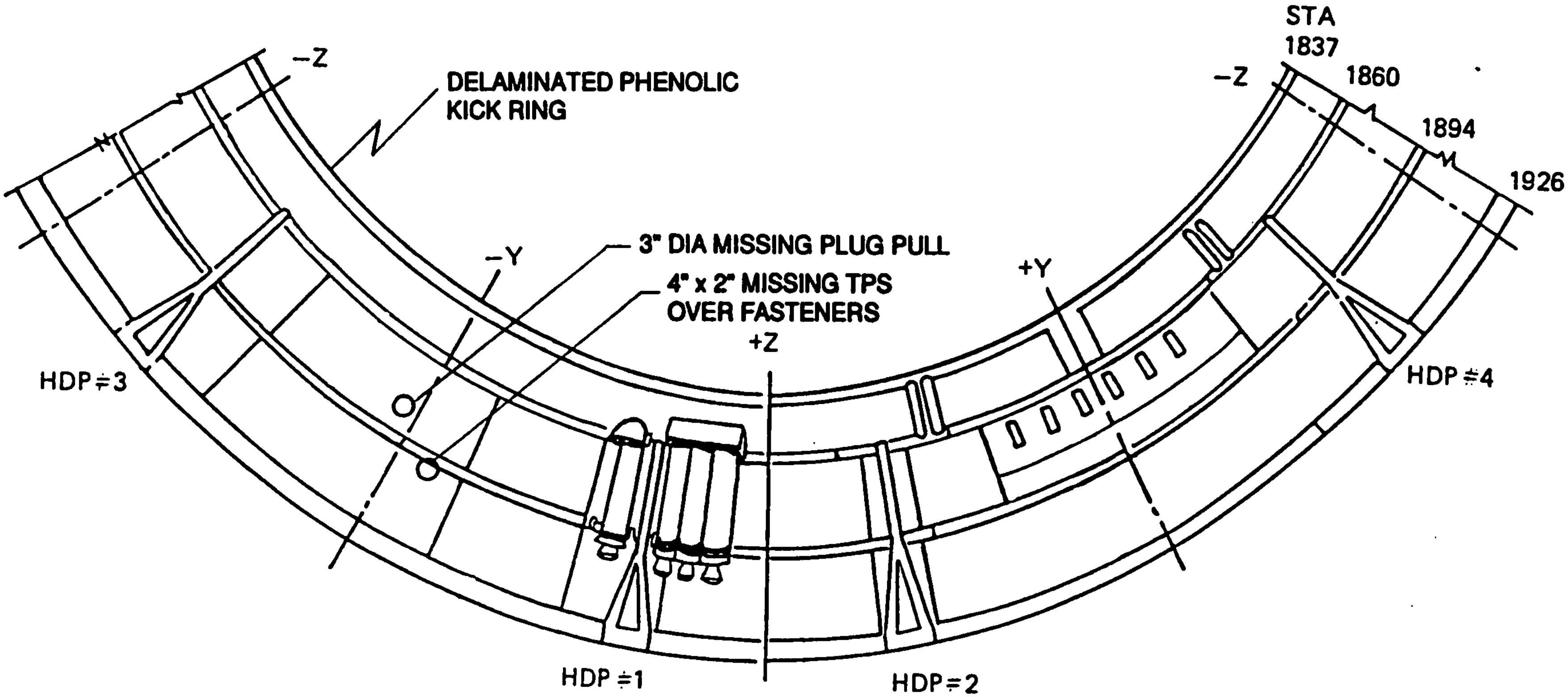
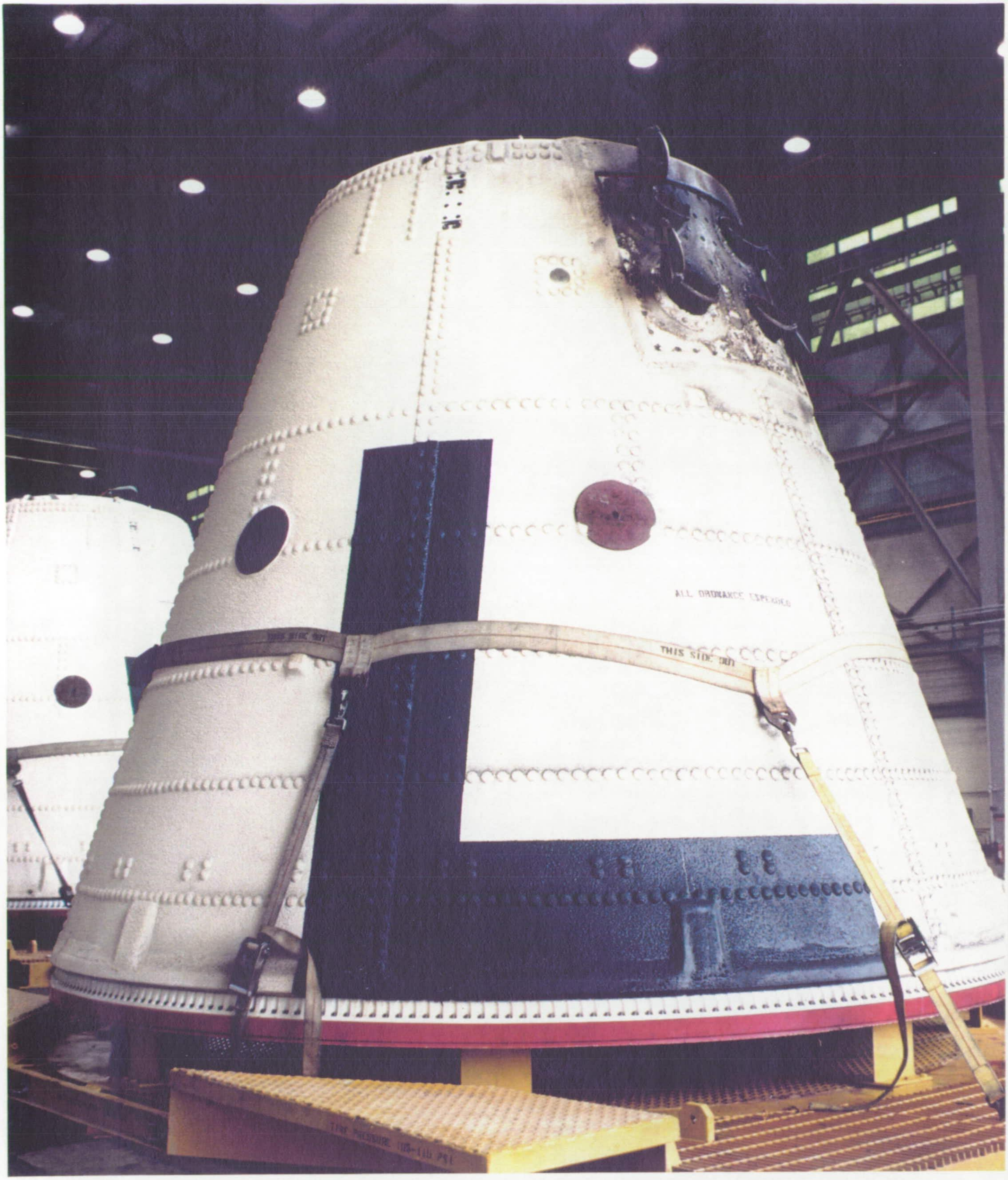


Figure 6. **RIGHT SRB AFT SKIRT EXTERIOR TPS**

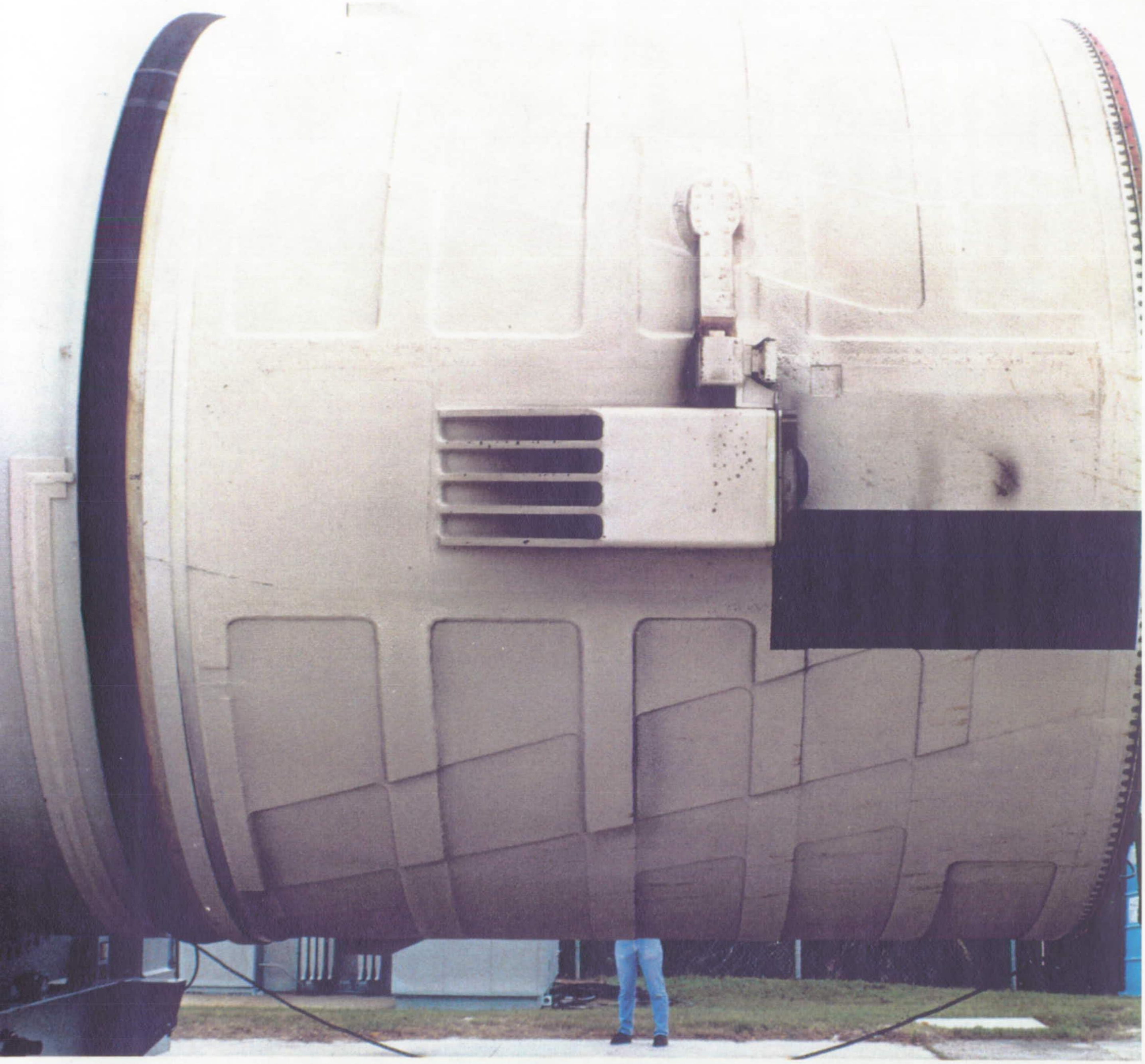


ALL DCS PLUNGERS
PROPERLY SEATED

EGG/V 326C

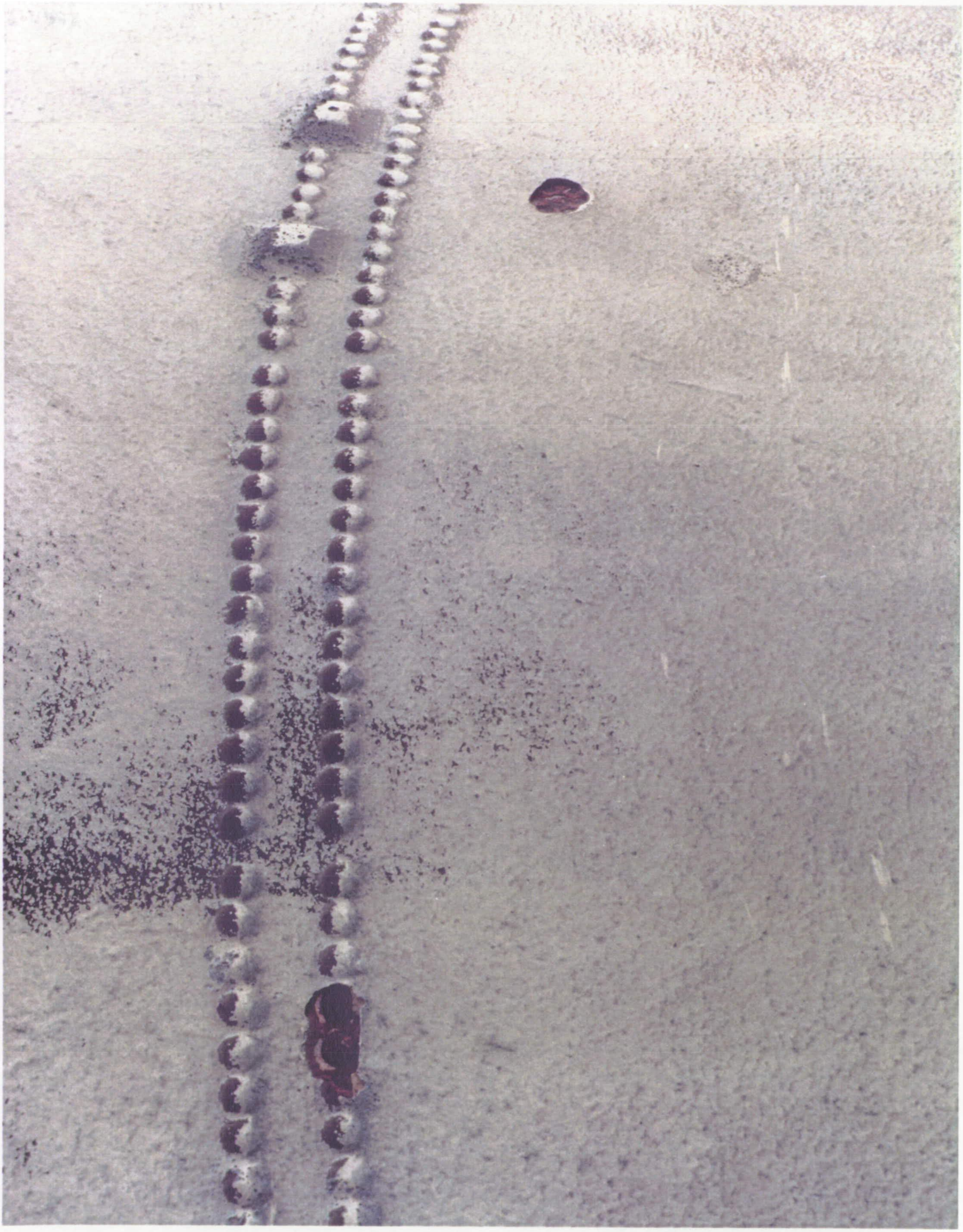


The RH frustum had 42 MSA-2 debonds over fasteners and one area of missing TPS at the -Y axis near the 275 ring frame. All BSM aero heat shield covers were locked in the fully opened position though the left two cover attach rings had been bent by parachute riser entanglement.

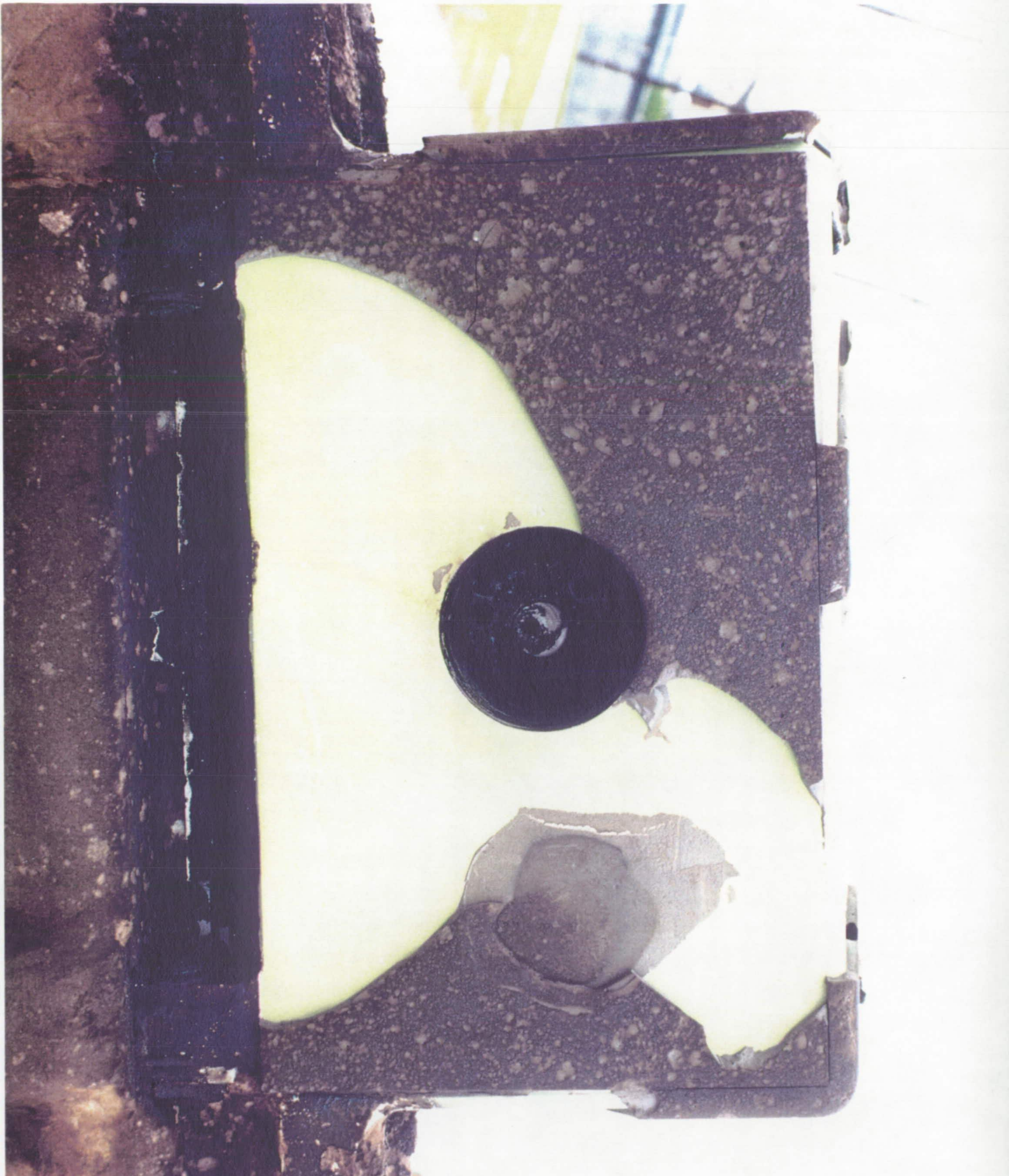


The RH forward skirt exhibited no debonds or missing TPS. Minor blistering of the Hypalon paint occurred in localized areas. Both RSS antenna covers/TPS were intact though the +Z antenna phenolic plate was delaminated.

Post flight condition of the RH aft booster. MSA-2 TPS was missing from three areas on the aft skirt acreage. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage.



MSA-2 TPS was missing from two areas over aft skirt fasteners



A 3-inch diameter piece of the HDP #4 EPON shim was missing prior to water impact (sooted/charred substrate).

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum had 25 MSA-2 debonds over fasteners and was missing MSA-2 (1.5-inch diameter) from one location between the +Y and +Z axes on the 381 ring frame (Figure 7). There was minor localized blistering of the Hypalon paint. The BSM aero heatshield covers were locked in the fully opened position.

The LH forward skirt exhibited no debonds or missing TPS. The phenolic plates on both RSS antennae were intact and undamaged (Figure 8). The forward separation bolt and electrical cables appeared to have separated cleanly. No pins were missing from the frustum severance ring. Minor blistering of the Hypalon paint occurred near the ET/SRB attach point and on the systems tunnel cover.

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

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The upper strut fairing was missing a 5" x 2" area of K5NA and the substrate was charred. All three aft booster stiffener rings sustained water impact damage. The aft booster forward and center stiffener ring splice plate closeouts were intact and no K5NA material was missing. However, a 6"x3" piece of K5NA was missing from the aft stiffener ring. Though the remaining material showed signs of delamination, the surfaces were not sooted indicating the material was most likely lost at water impact.

The phenolic material on the kick ring was delaminated. The K5NA closeouts (protective domes) on the kick ring forward and aft fasteners had been eliminated. RTV-133 replaced the K5NA over the forward fasteners. Three divots, measuring 2" in diameter (two places near the BSM's) and 2"x1" (one place near HDP #7), occurred on the aft skirt acreage TPS (Figure 9).

All four Debris Containment System (DCS) plungers were properly seated. This was the tenth flight utilizing the optimized link. Pieces of EPON shim material were missing from HDP #7 prior to water impact (sooted/charred substrate).

Figure 7. **LEFT SRB FRUSTUM**

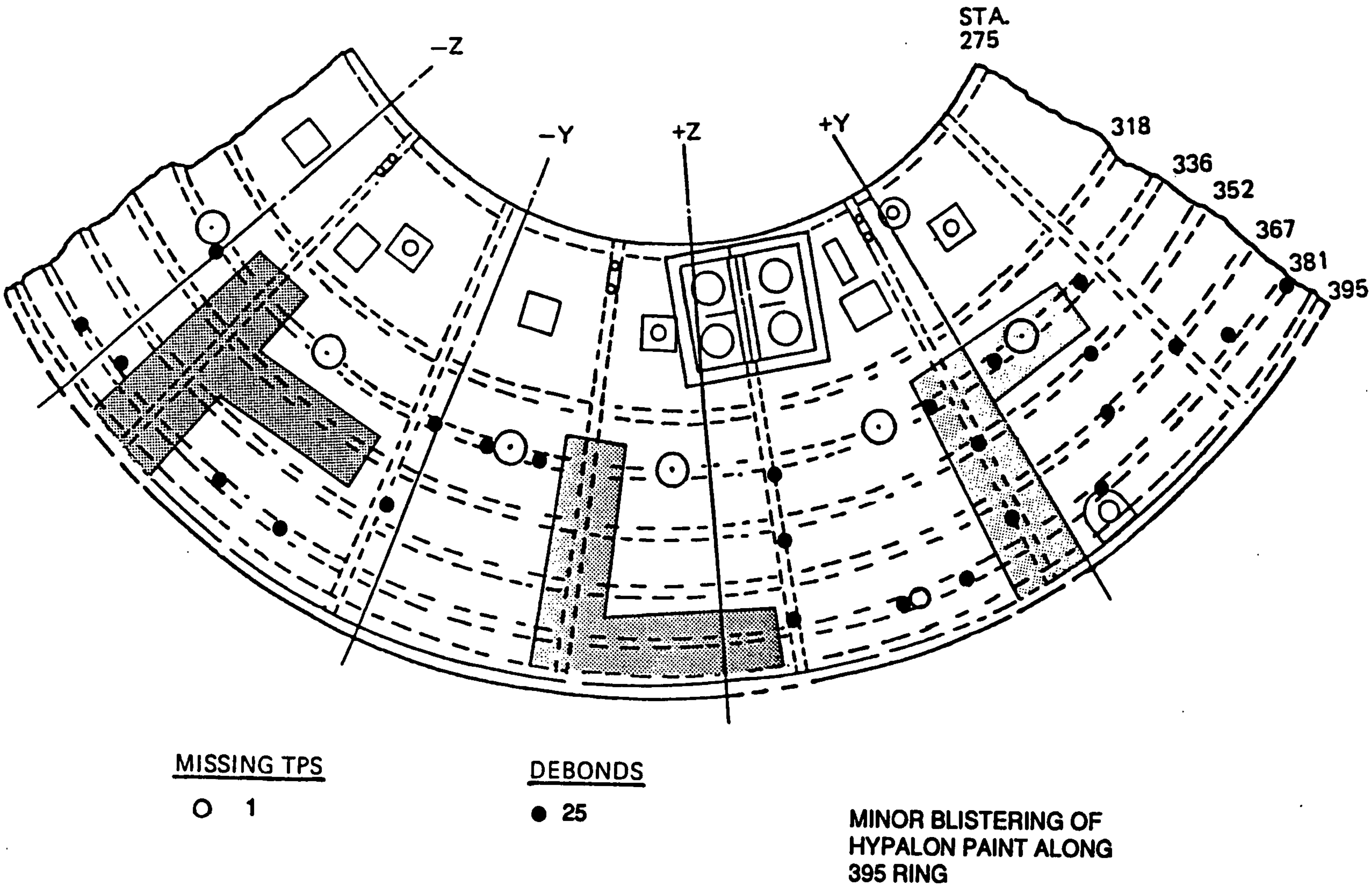
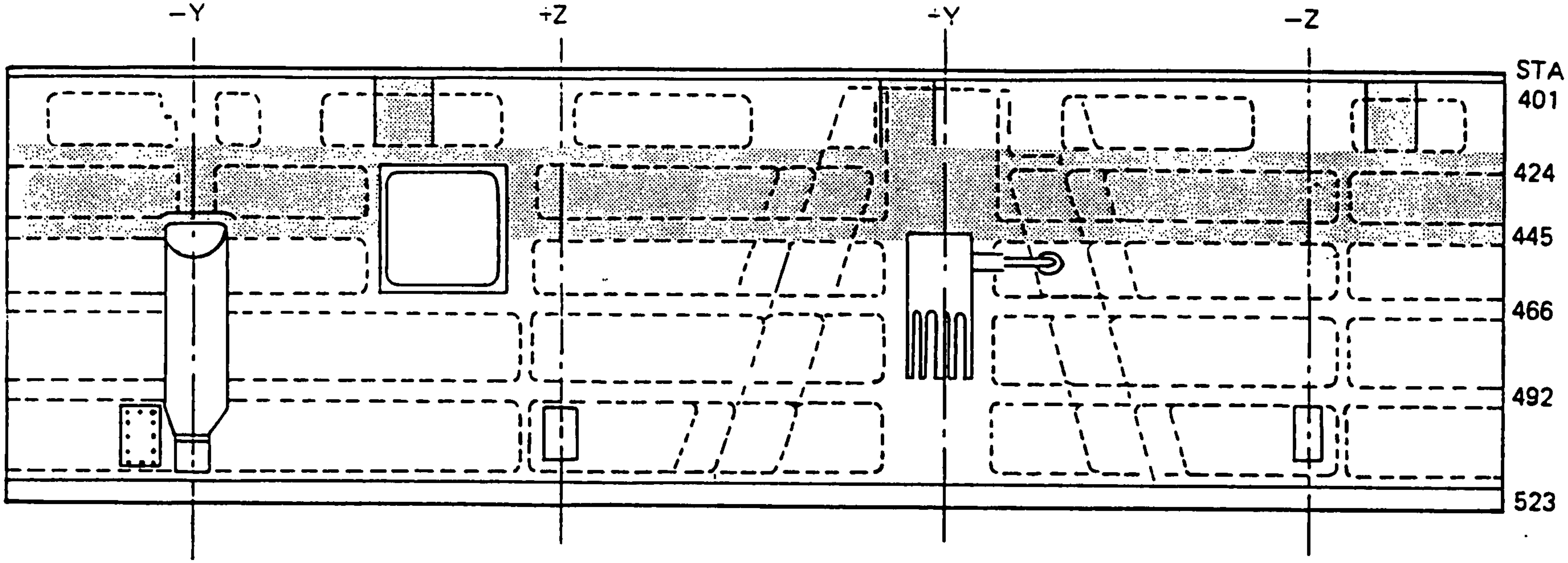


Figure 8. **LEFT SRB FWD SKIRT**



TPS MISSING

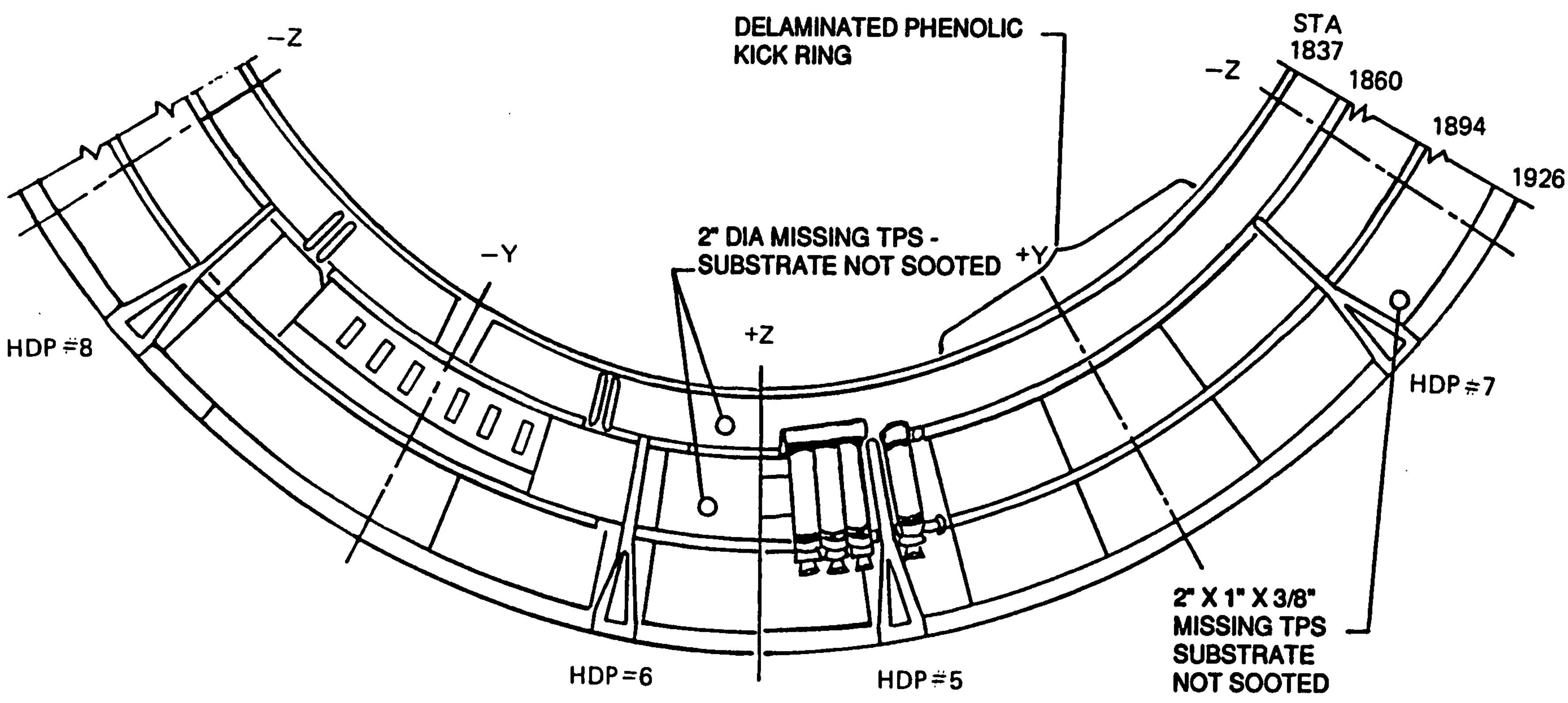
NONE

DEBONDS

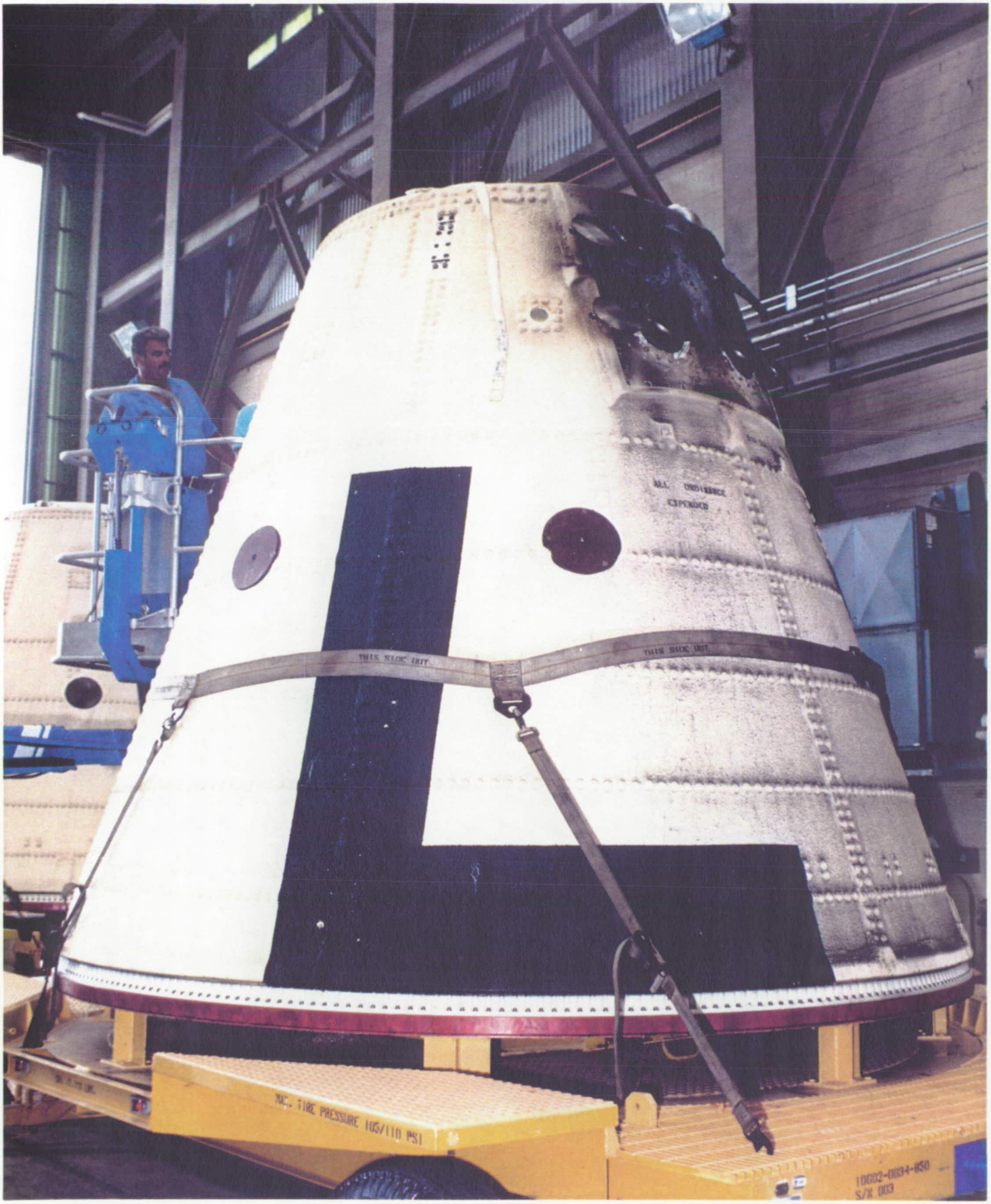
NONE

MINOR BLISTERING OF
HYPALON PAINT ON
SYSTEMS TUNNEL COVER
AND ET/SRB ATTACH FITTING

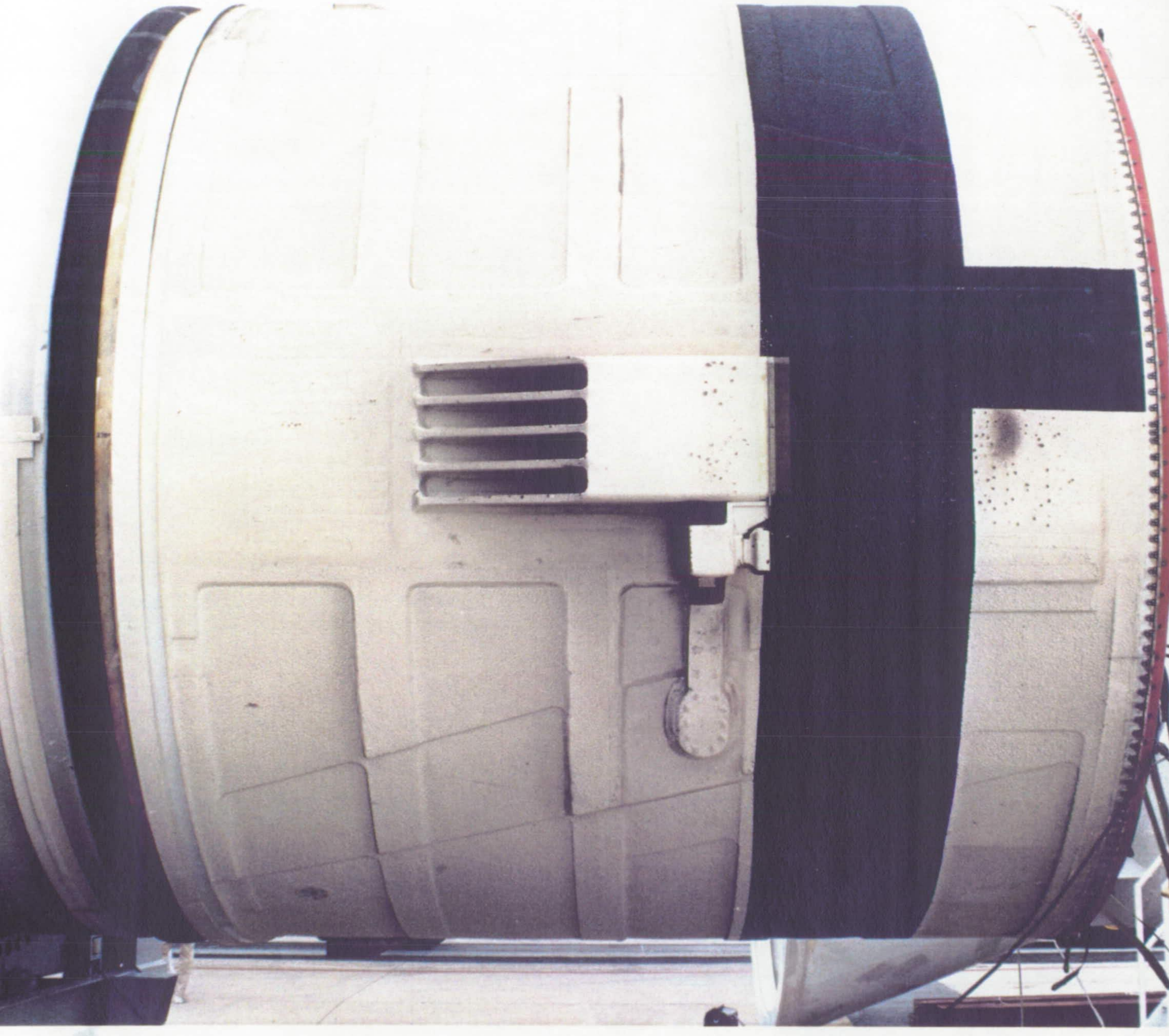
Figure 9. **LEFT SRB AFT SKIRT EXTERIOR TPS**



ALL DCS PLUNGERS
PROPERLY SEATED



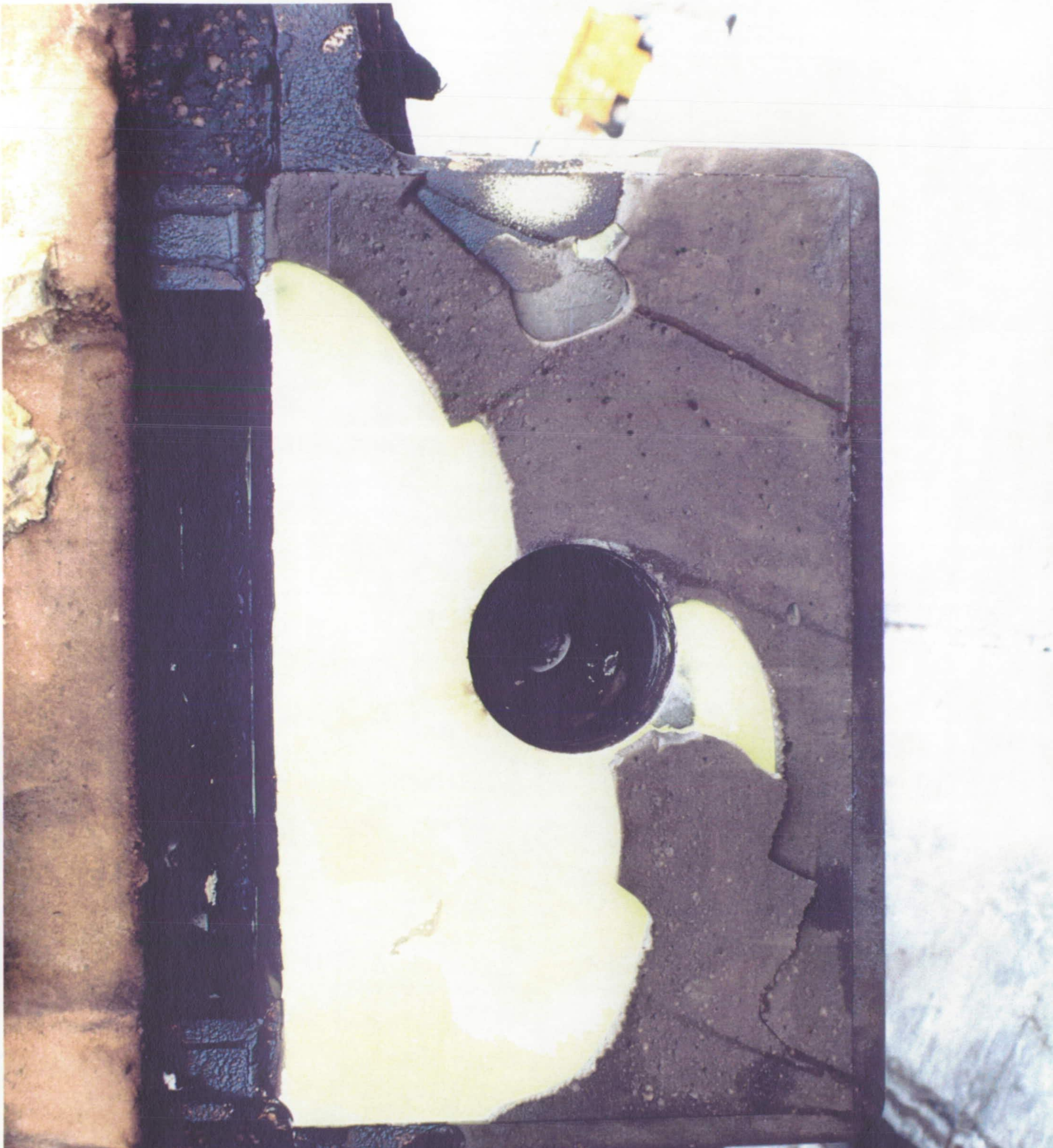
The LH frustum had 25 MSA-2 debonds over fasteners and was missing MSA-2 from one location between the +Y and +Z axes on the 381 ring frame. The BSM aero heat shield covers were locked in the fully opened position.



The LH forward skirt exhibited no debonds or missing TPS. Minor blistering of the Hypalon paint occurred in localized areas. Both RSS antenna covers/TPS were intact and undamaged.

Post flight condition of the LH aft booster. Three MSA-2 divots were present on the aft skirt acreage. The ET/SRB aft struts, ETA ring, and IEA appeared undamaged. All three aft booster stiffener rings sustained water impact damage.

A 6"x3" piece of K5NA was missing from the aft stiffener ring. Though the remaining material showed signs of delamination, the surfaces were not sooted indicating the material was most likely lost at water impact.



Pieces of the HDP #7 EPON shim were missing prior to water impact (sooted/charred substrate).

6.3 RECOVERED SRB DISASSEMBLY FINDINGS

Post flight disassembly of the Debris Containment System (DCS) housings revealed an overall system retention of 99 percent and individual holddown post retention percentages as listed:

HDP #	% of Nut without 2 large halves	% of Ordnance fragments	% Overall
1	99	94	99
2	99	94	99
3	99	98	99
4	99	96	99
5	99	96	99
6	99	93	99
7	99	94	99
8	99	93	99

STS-47 was the tenth 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.

SRB Post Launch Anomalies are listed in Section 9.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-105 (Endeavour) was conducted on September 20-21, 1992, 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 108 hits, of which 11 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 34 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42 which had damage from known debris sources), indicates that the both the total number of hits and the number of hits one inch or larger are less than average. Figures 10-13 show the TPS debris damage assessment for STS-47.

The Orbiter lower surface sustained a total of 47 hits, of which 3 had a major dimension of one inch or greater. These figures are much less than average (reference Figure 17). 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-47 Orbiter debris damage by area:

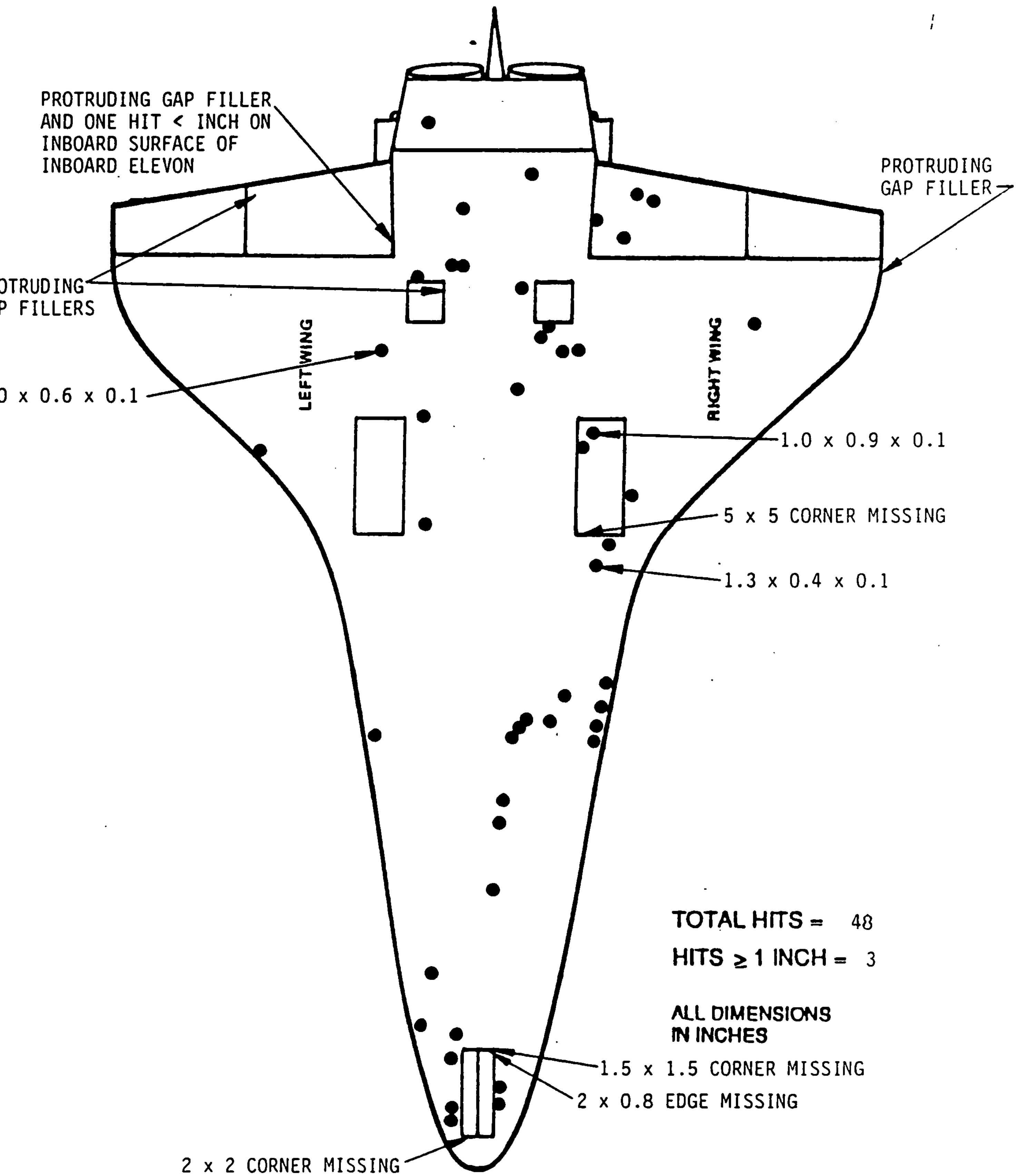
	HITS > 1"	TOTAL HITS
Lower surface	3	48
Upper surface	3	37
Right side	2	3
Left side	0	3
Right OMS Pod	2	8
Left OMS Pod	1	9
TOTALS	11	108

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

The EO-3 (LO2) ET/Orbiter separation device plunger was obstructed by two ordnance fragments and did not seat properly. The EO-1 and EO-2 separation devices appeared to have functioned properly. No flight hardware was found on the runway below the umbilicals when the ET doors were opened.

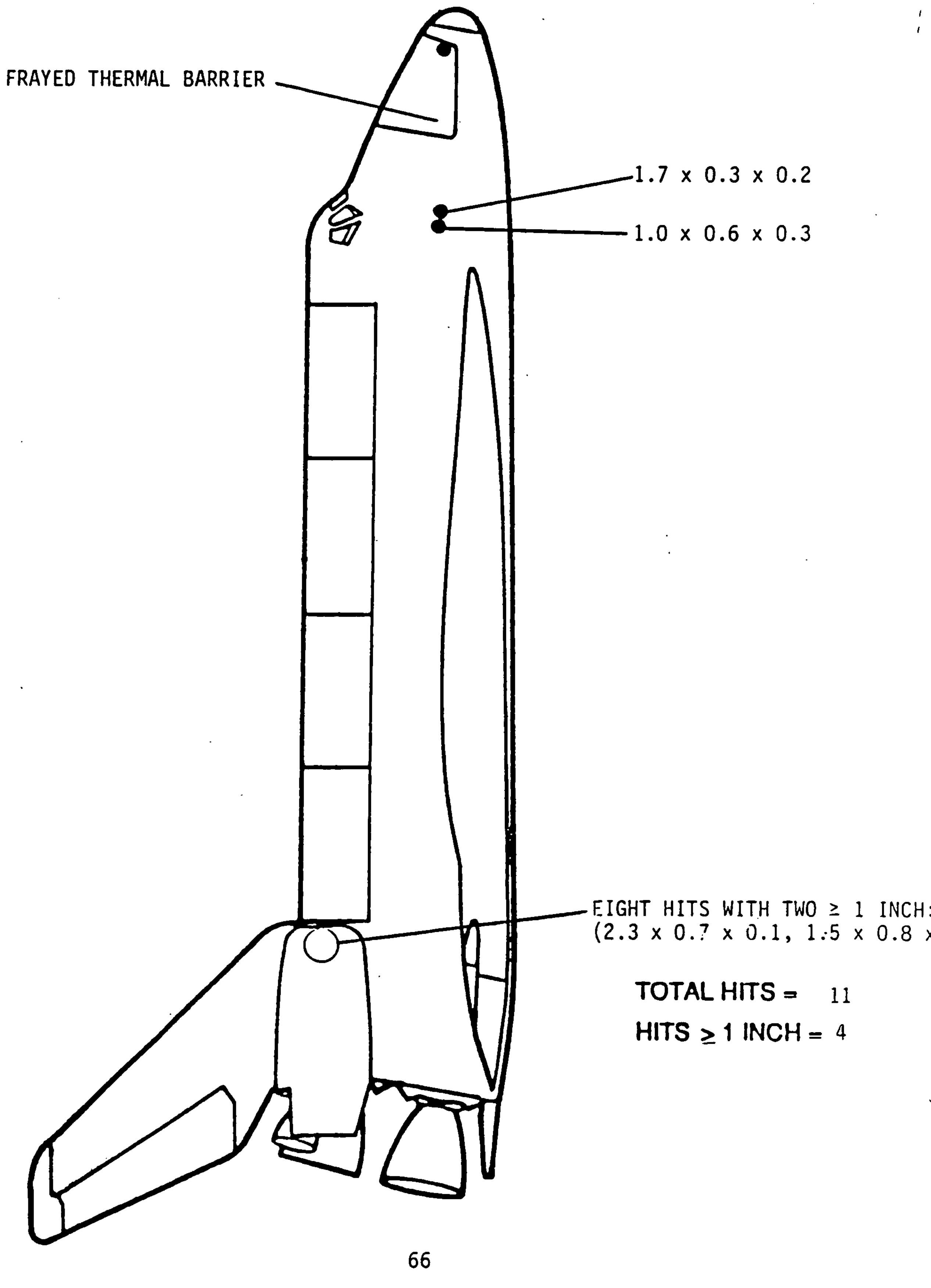
STS-47

Figure 10. DEBRIS DAMAGE LOCATIONS



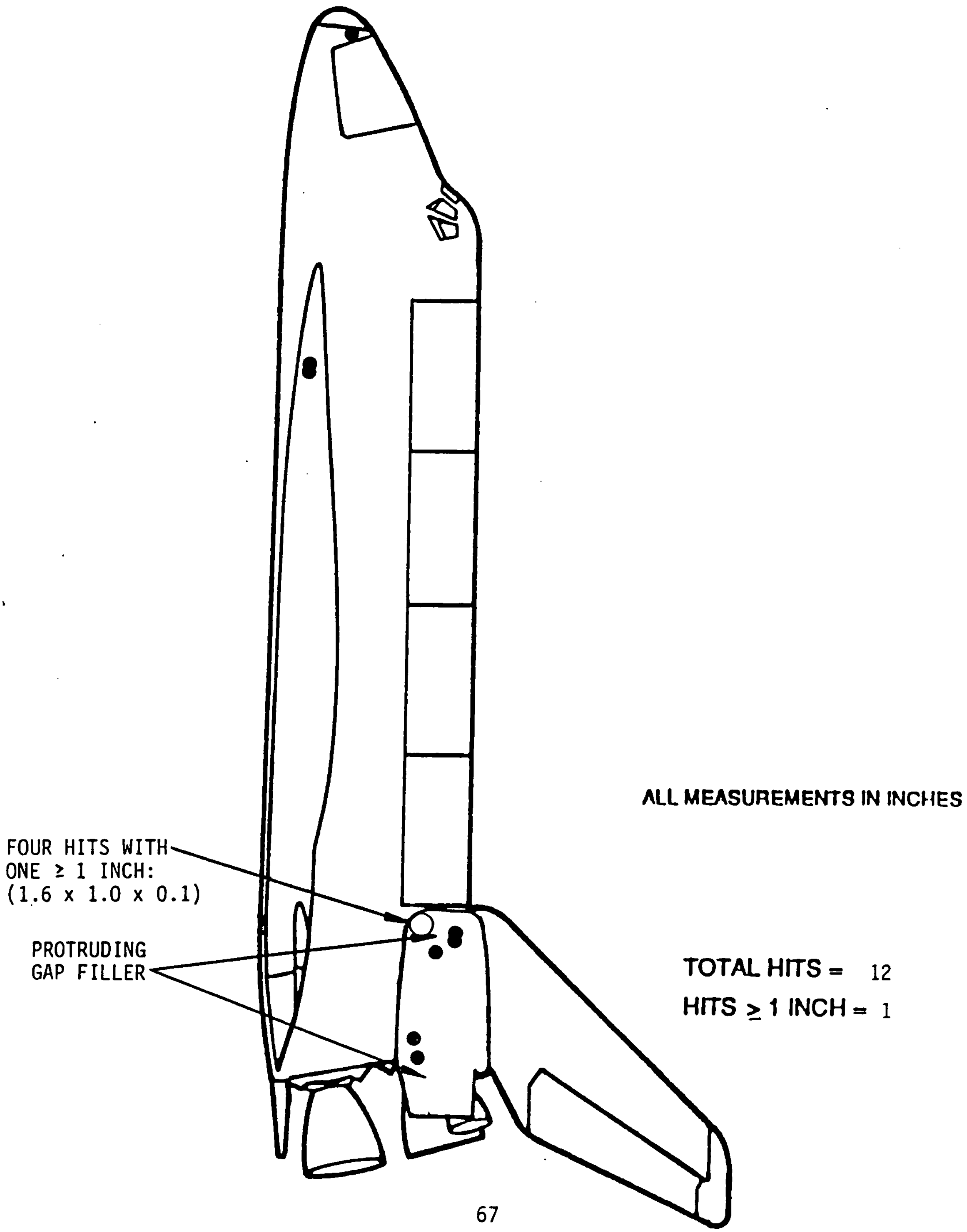
STS-47

Figure 11. **DEBRIS DAMAGE LOCATIONS**



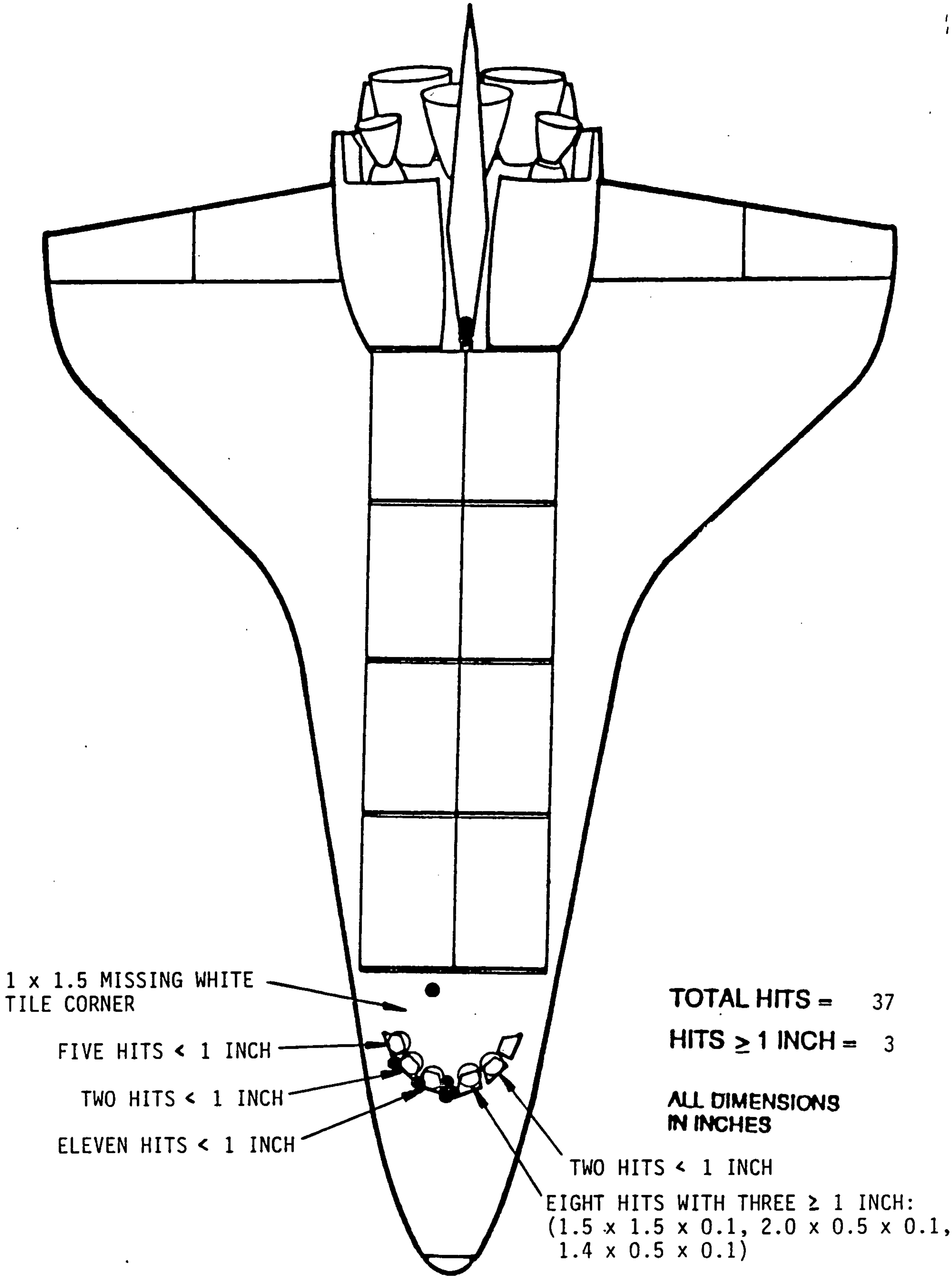
STS-47

Figure 12. **DEBRIS DAMAGE LOCATIONS**



STS-47

Figure 13. **DEBRIS DAMAGE LOCATIONS**



Damage to the base heat shield tiles was less than average. The SSME #1 Dome Mounted Heat Shield (DMHS) closeout blanket splice at the 6:00 o'clock position exhibited minor fraying. All of the remaining DMHS blankets were in excellent condition.

The LH rudder/speedbrake split-line thermal barrier was protruding slightly and exhibited minor fraying, but did not appear to be significantly damaged or deformed.

Orbiter windows #3 and #4 exhibited light hazing with a few streaks. Hazing on the other windows was less than usual. Surface wipes were taken from all forward facing windows (#1 through #6) for laboratory analysis (reference Figure 14). Detailed examination of the windows revealed on-orbit debris impacts to windows #5, 6, and 7. The depth of the impacts ranged from 0.0041 to 0.0056 inches, which exceeded the drawing acceptance criteria of 0.0006 inches. All three windows will be removed and replaced. Twenty-eight tile impact sites (including three larger than one inch) were noted on the perimeter tiles around windows #2 through #6. All of these hits were shallow in depth and may have been caused by the RTV used to bond paper covers to the FRCS nozzles, exhaust products from the SRB booster separation motors, or ice/TPS debris from the External Tank LO2 tank.

Samples were taken from other selected sites for laboratory analysis (reference Figure 14).

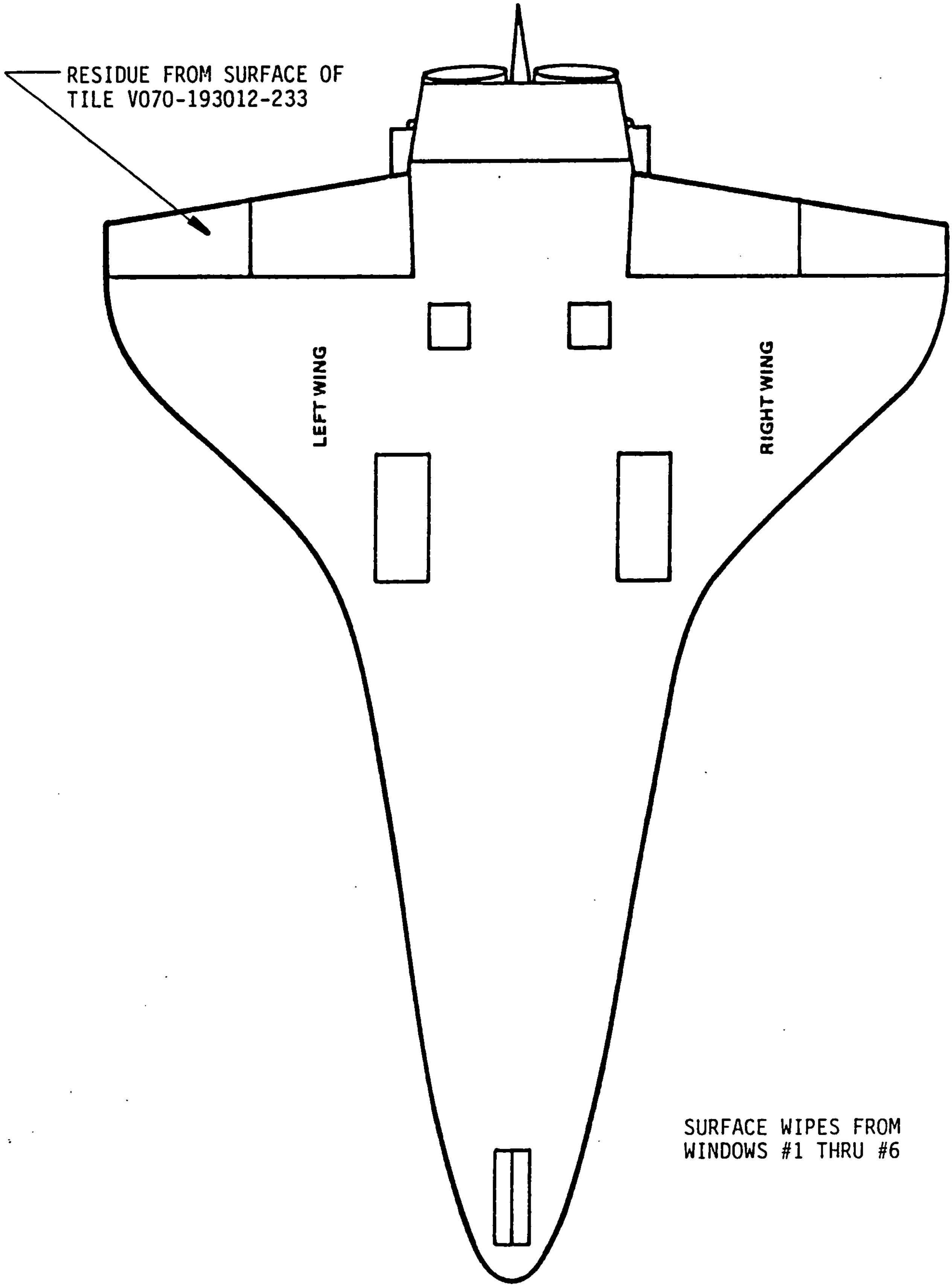
Runway 33 was inspected and swept by KSC EG&G SLF personnel on 19 September 1992 and all potentially damaging debris was removed. A post landing inspection of Runway 33 was performed immediately after landing. The only unexpected flight hardware found were numerous pieces of tile material from the vertical stabilizer "stinger" and a piece of red RTV material from the RH outboard Main Landing Gear tire pressure instrumentation cable.

This flight marked the third use of the Orbiter drag chute. The drag chute appeared to have functioned nominally. However, three tiles on the LH edge of the vertical stabilizer "stinger" suffered significant damage/material loss due to contact with the riser lines during chute deployment. Another tile, on the lower (-Z) RH edge of the drag chute opening, was slightly damaged by separation of the chute compartment door. All drag chute hardware was recovered and showed no signs of abnormal operation (reference Figure 15 for recovery locations).

A portable Shuttle Thermal Imager (STI) was used to measure the surface temperatures of three areas on the Orbiter (per OMRSD V09AJ0.095). Eighteen minutes after landing, the Orbiter Reinforced Carbon-Carbon (RCC) nosecap was 165 degrees Fahrenheit (F). Twenty-one minutes after landing the RH wing leading edge RCC panel #9 was 112 degrees F, and panel #17 was 113 degrees F (reference Figure 16).

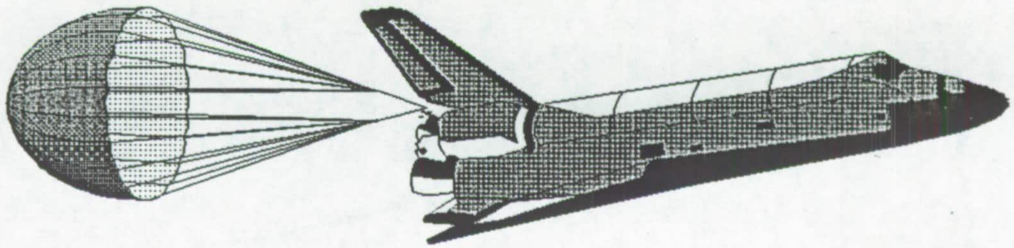
STS-47

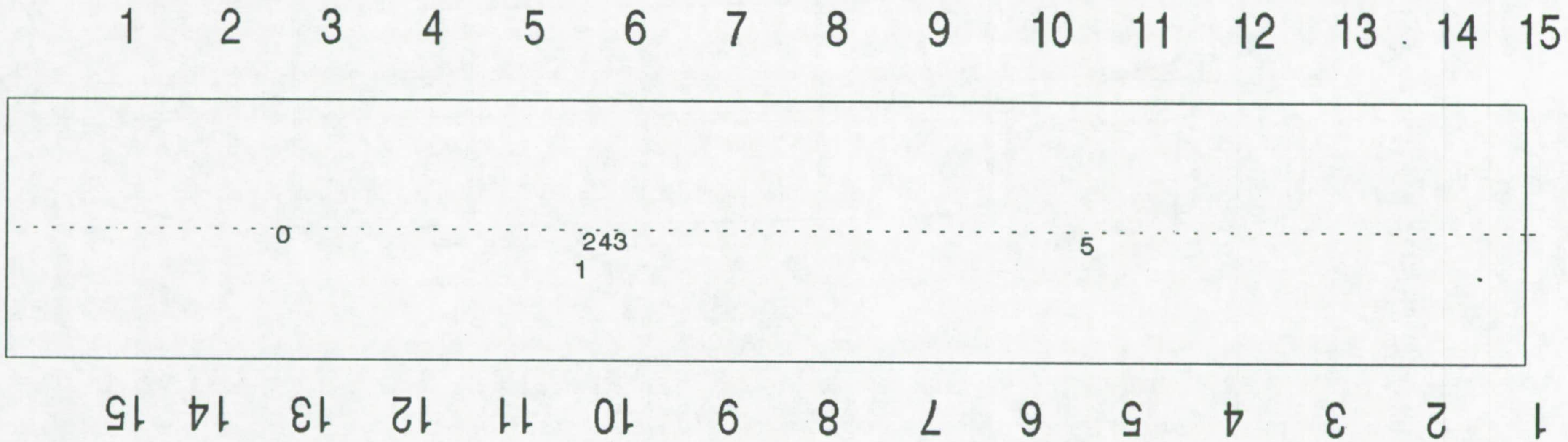
Figure 14. **CHEMICAL SAMPLE LOCATIONS**



RECOVERY LOCATIONS OF DRAG CHUTE COMPONENTS

Figure 15.



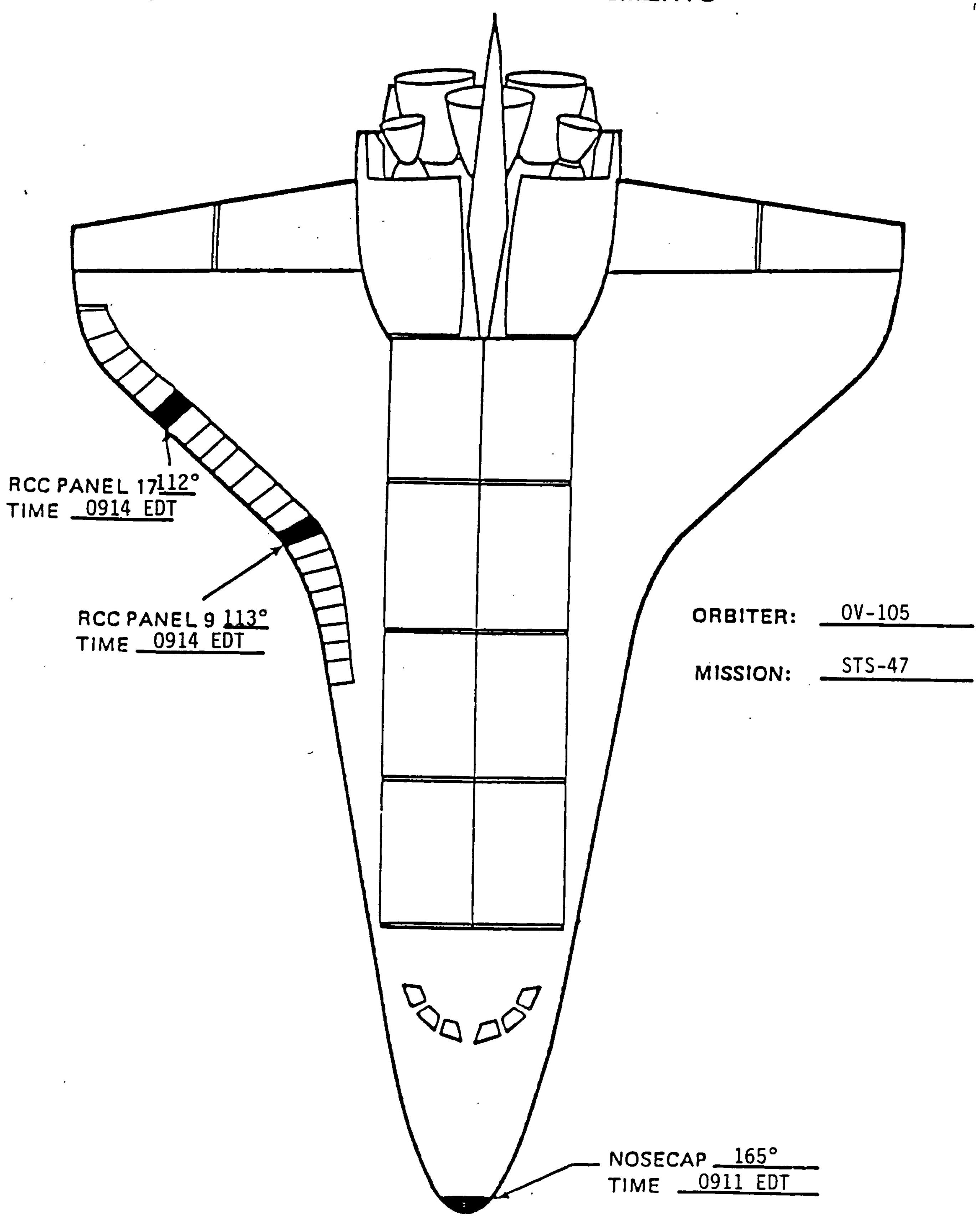


0 (MLG TOUCHDOWN): 2500'
1 (MORTAR COVER): 5500', 90' R OF C/L
2 (SABOT): 5650', 25' R OF C/L
3 (DOOR): 5900', 30' R OF C/L
4 (PILOT CHUTE): 5670', 25' R OF C/L
5 (MAIN CHUTE): 10300', 30' R OF C/L

STS-47
OV-105
ENDEAVOUR
9/20/92

STS-47

Figure 16. TEMPERATURE MEASUREMENTS



In summary, the number of Orbiter TPS debris hits was less than average when compared to previous missions (reference Figures 17 and 18). From a debris damage standpoint, this flight represents one of the best in the Space Shuttle Program.

Orbiter Post Launch Anomalies are listed in Section 9.

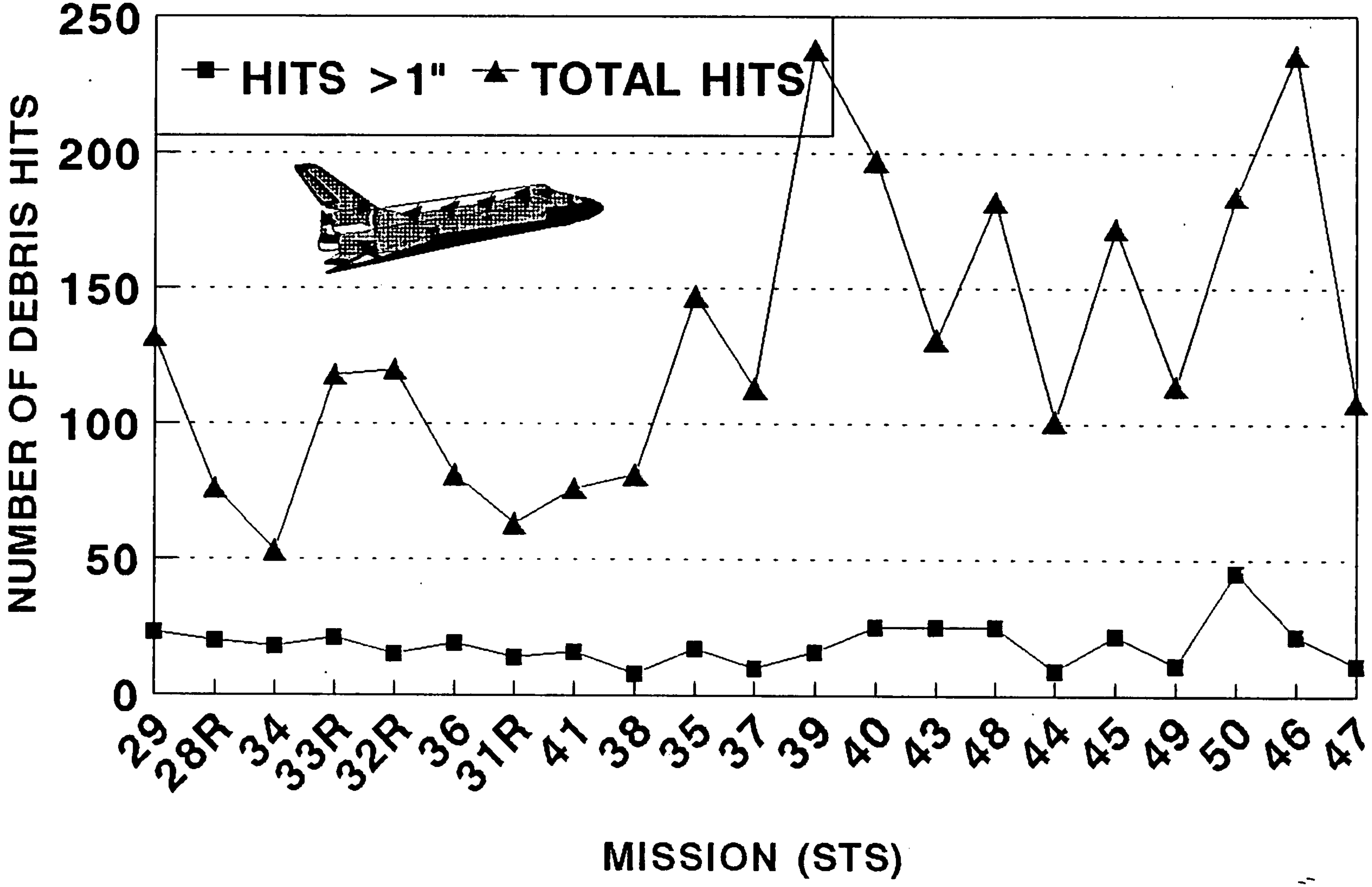
FIGURE17: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	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
AVERAGE	15.4	91.6	22.7	125.5
SIGMA	7.5	46.7	11.1	56.8
STS-47	3	48	11	108

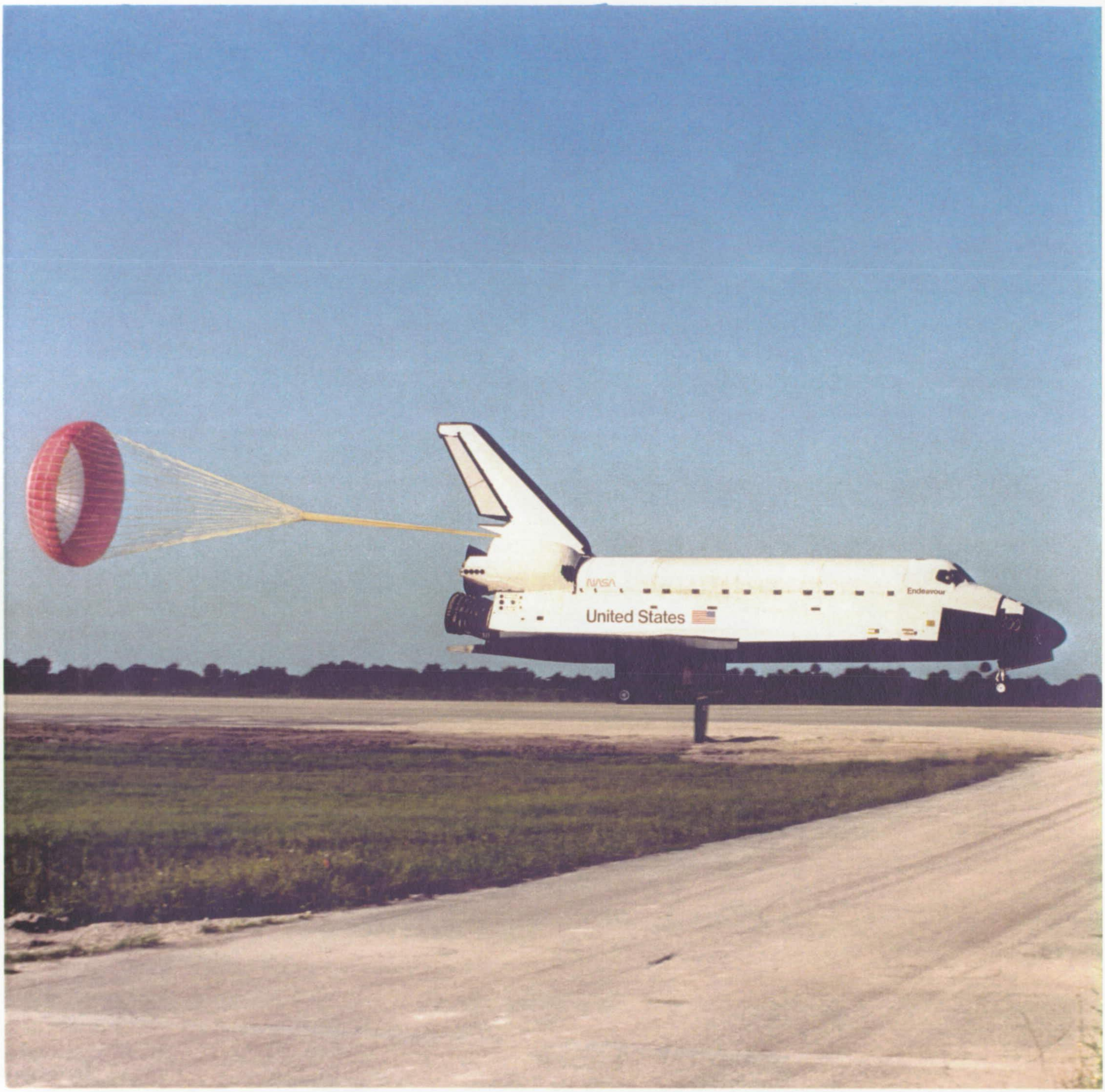
MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

ORBITER TPS DEBRIS DAMAGE
STS-29 THROUGH STS-47

Figure 18.



EXCLUDES MISSIONS STS-30R AND 42 WHICH EXPERIENCED SIGNIFICANT DAMAGE FROM KNOWN DEBRIS SOURCES

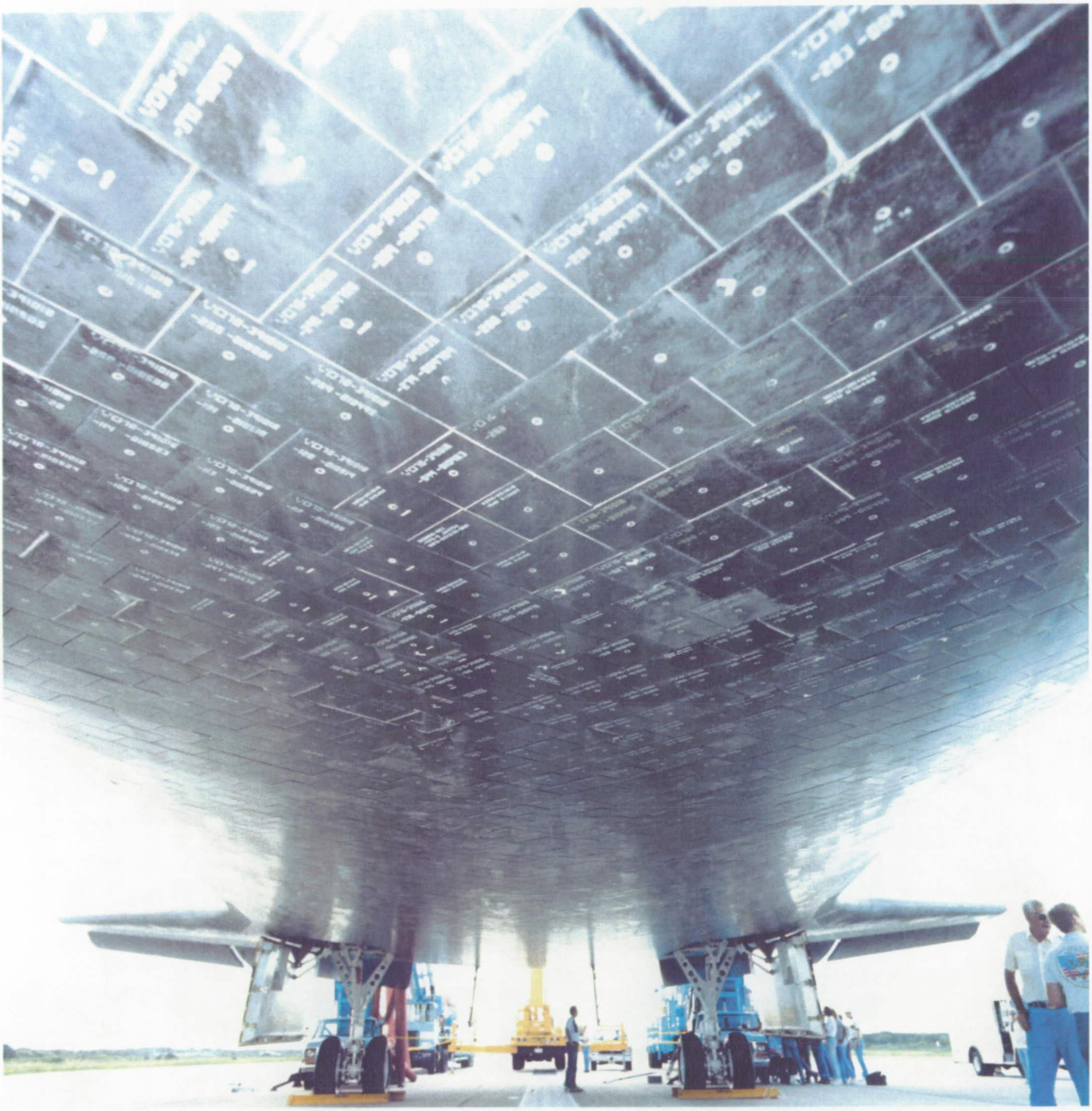


OV-105 Endeavour landed at the Kennedy Space Center
Shuttle Landing Facility Runway 33 on 20 September 1992

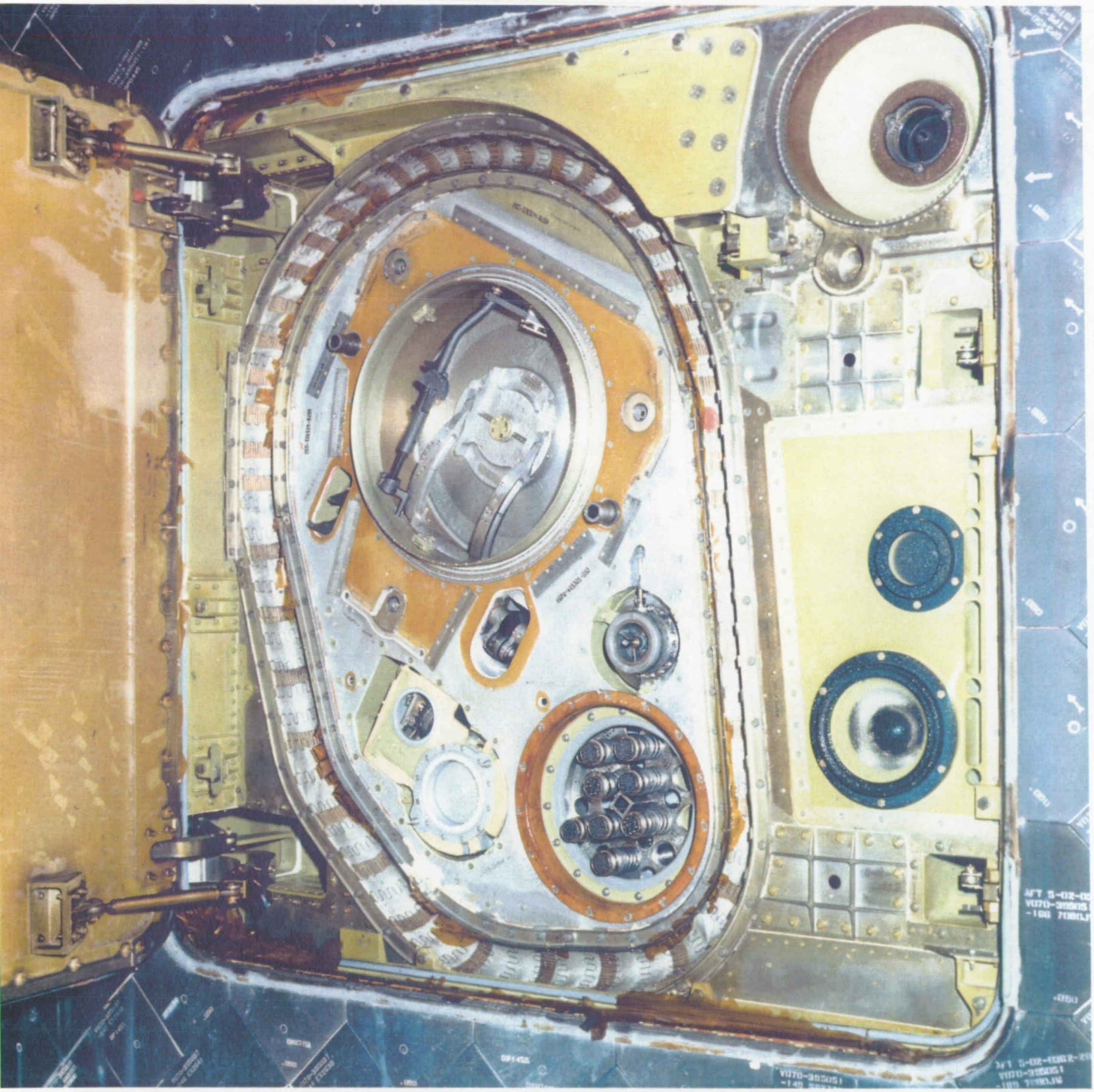
Overall view of Orbiter left side

ORIGINAL PAGE
COLOR PHOTOGRAPH

Overall view of Orbiter right side

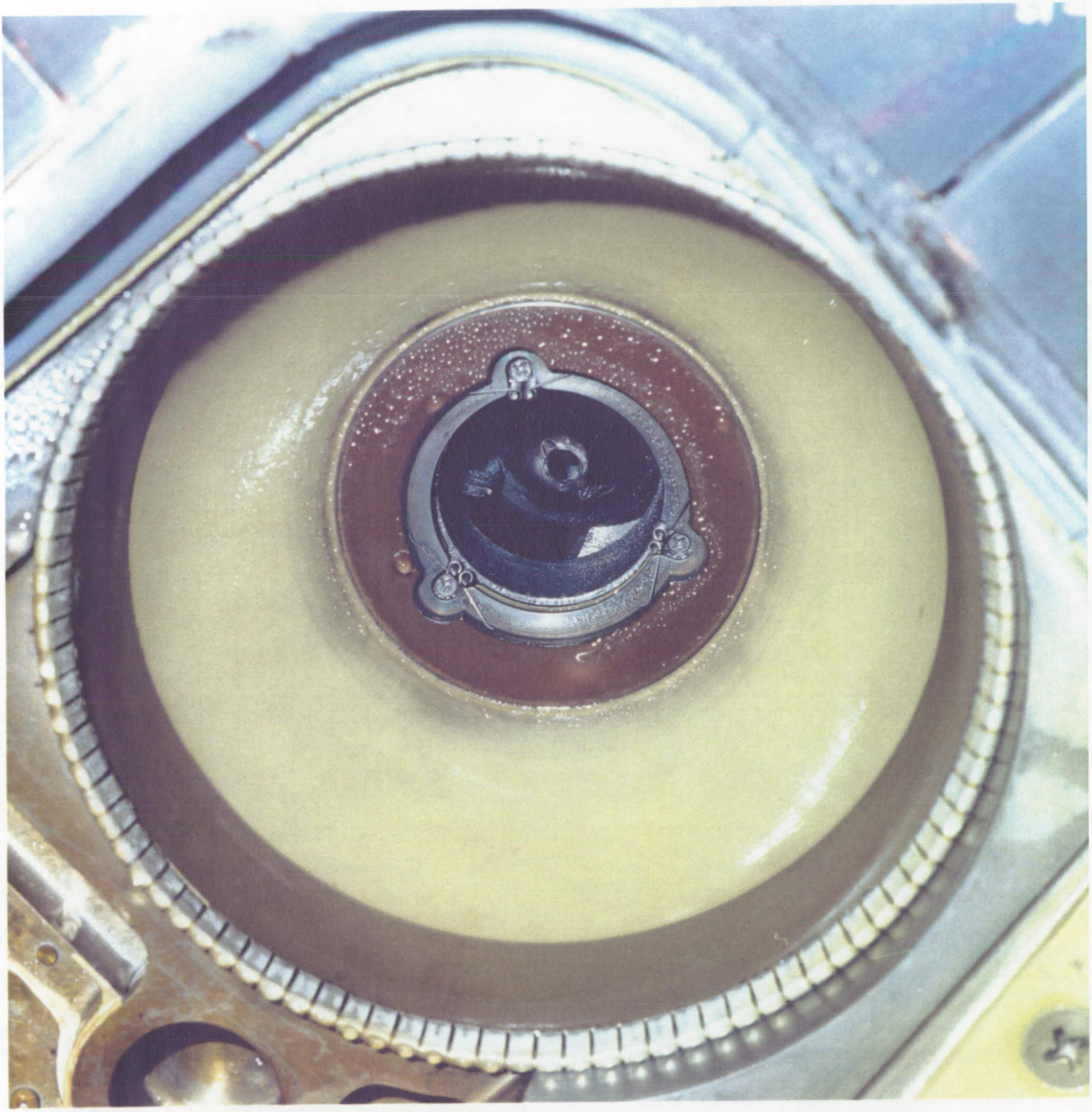


The Orbiter lower surface tiles sustained a total of 47 hits, of which three had a major dimension of 1-inch or greater. These numbers are much less than average.

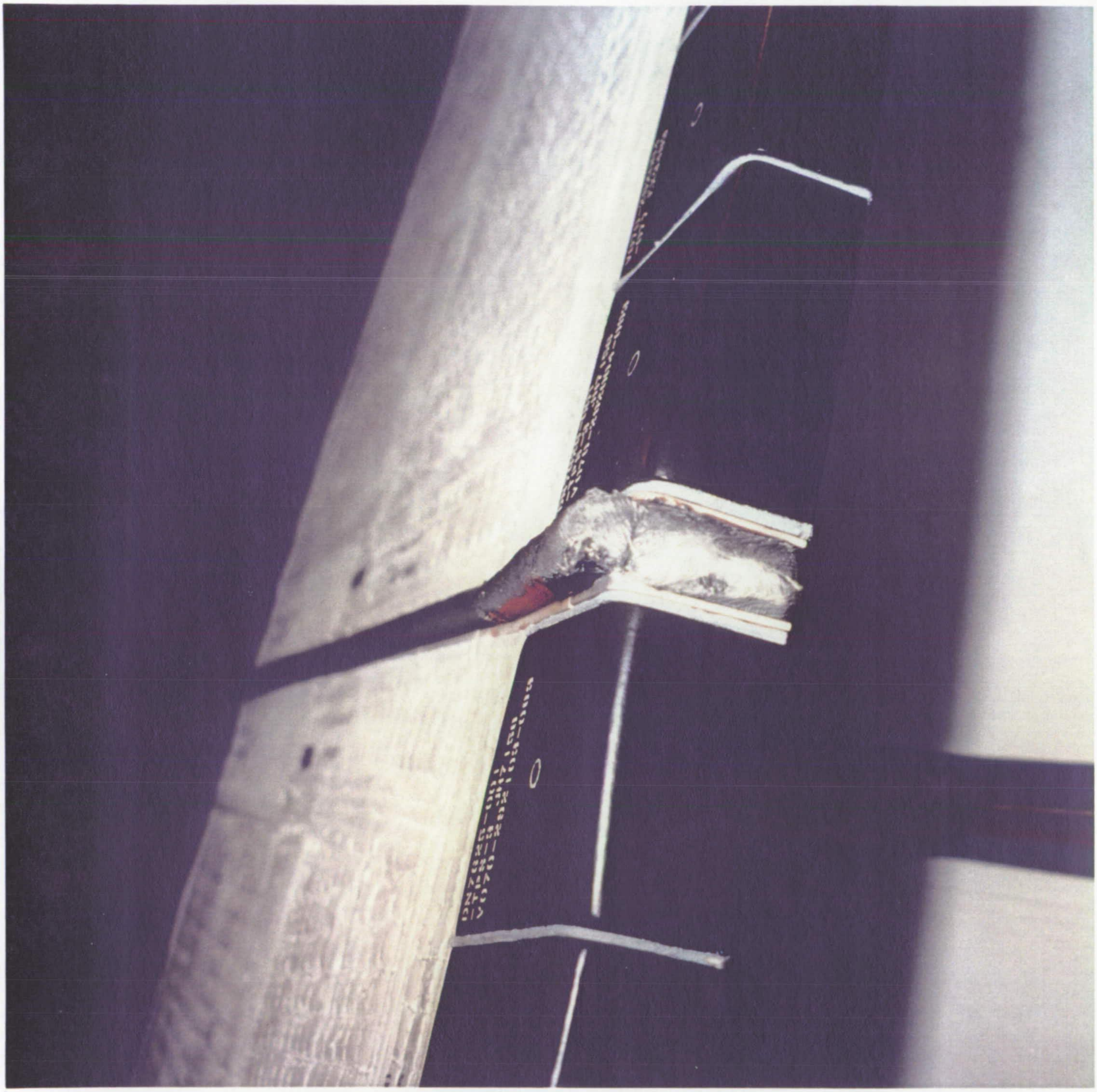


Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices appeared to have functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.

Overall view of the LO2 ET/ORB umbilical. No flight hardware was found on the runway below the umbilical when the ET door was opened.



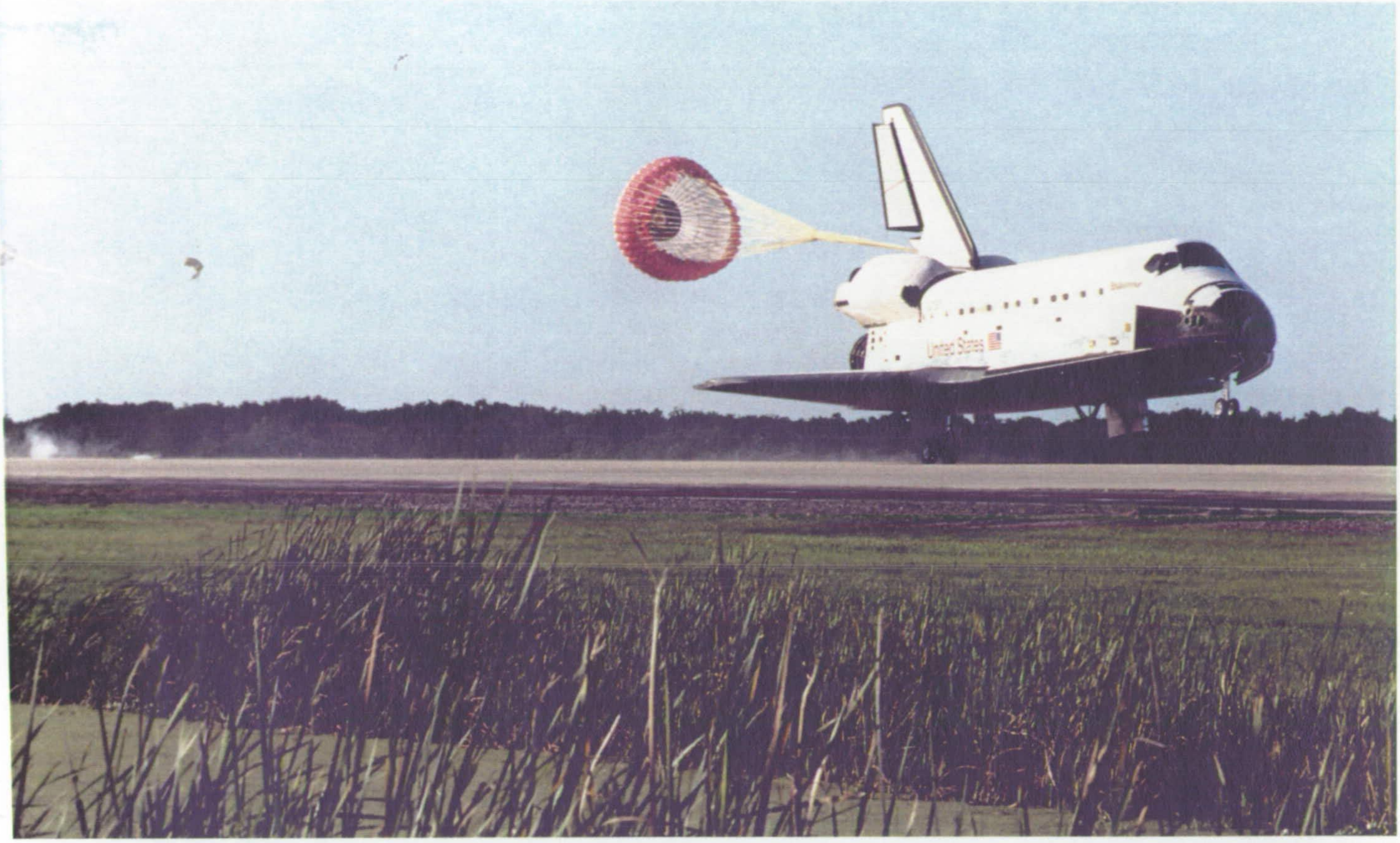
The EO-3 (LO2) separation device debris plunger was obstructed by two ordnance fragments and was prevented from seating

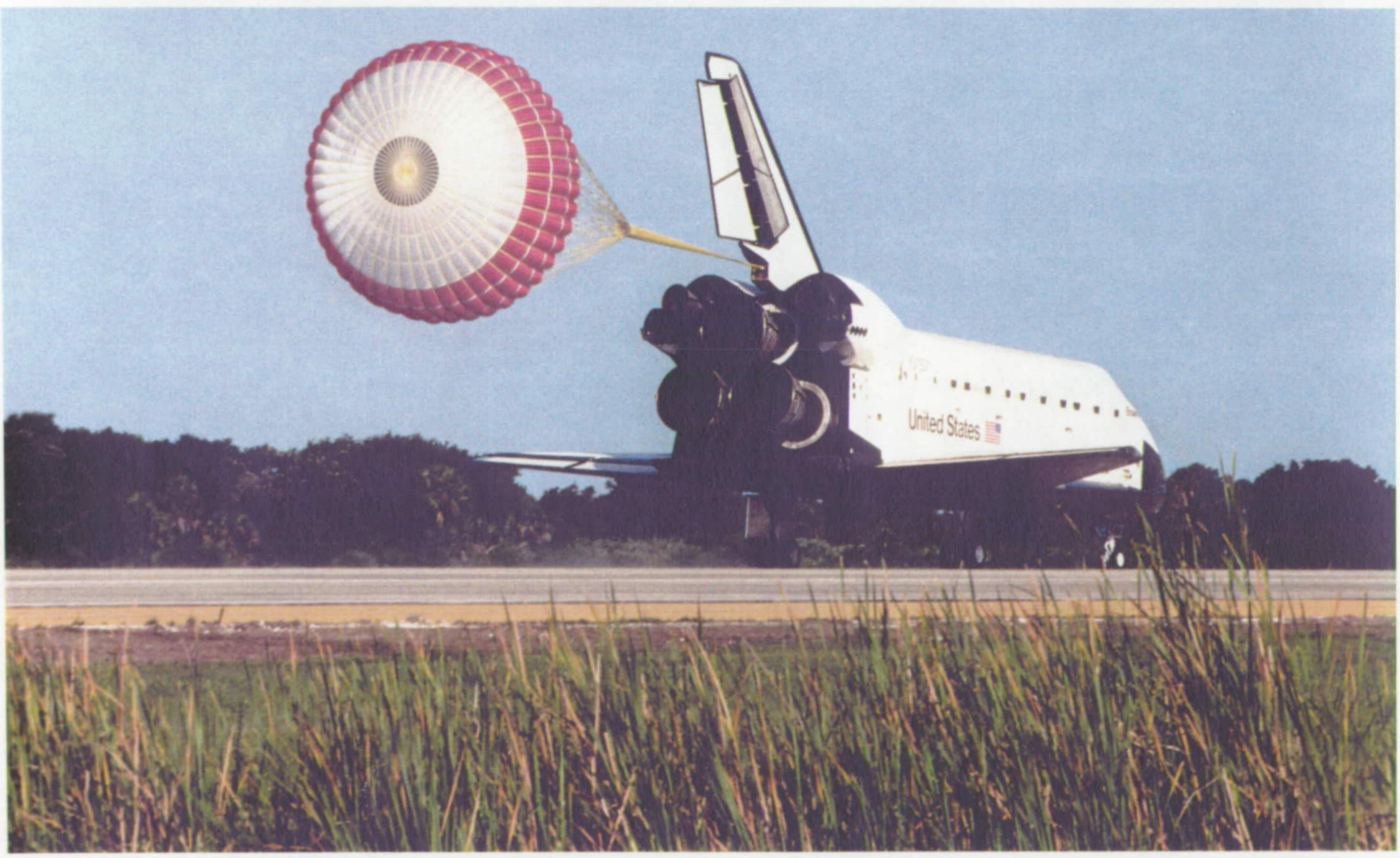


The LH rudder/speed brake split-line thermal barrier was protruding slightly and exhibited minor fraying, but did not appear significantly damaged or deformed.

Orbiter windows #3 and #4 exhibited light hazing with a few streaks. Hazing on the other windows was less than usual.

Inspection of Runway 33 immediately after landing revealed numerous pieces of tile material from the vertical stabilizer "stinger" and a piece of red RTV material from the RH outboard main landing gear tire pressure instrumentation cable.





This flight marked the third use of the Orbiter drag chute. The drag chute itself appeared to have functioned normally

Three tiles on the left edge of the vertical stabilizer "stinger" sustained significant damage/material loss due to contact with the riser lines during chute deployment.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of nine samples were obtained from OV-105 Endeavour during the STS-47 post landing debris assessment at Kennedy Space Center (reference Figure 14). The nine submitted samples consisted of 8 window wipes (Windows 1-8) and 1 scrape from a lower surface tile. 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 with respect to composition, thermal (mission) effects, and availability. Sample results and analyses are listed by Orbiter location in the following summaries:

Orbiter Windows

Results of the window sample analysis revealed the presence of the following materials:

1. Metallics
2. RTV, silica tile, insulation
3. Paints and rust
4. Cerium-rich material
5. Organics
6. Earth compounds

Debris analysis provides the following correlations:

1. Metallic particles (zinc, aluminum, stainless and carbon steel alloys) are common to SRB/BSM exhaust residue, but are not considered a debris concern in this quantity (micrometer) and have not generated a known debris effect.

2. RTV, silica tile, and insulation originate from Orbiter thermal protection system (TPS).

3. Paint is of flight hardware/facility/GSE origin, also detected was zinc-rich primer; rust is an SRB BSM exhaust residue.

4. Cerium-rich material is an Orbiter window polishing residue. Cerium is a rare earth element and not common to the landing site.

5. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity. Early analysis indicates some similar materials as reported in the STS-46 organic results.

6. Earth compounds (alpha-quartz, calcite, salts, and calcium-silica rich materials) originate from the landing site.

Lower Surface Tile (LH outboard elevon)

Results of the lower surface tile (LH outboard elevon) sample indicated the presence of the following material:

1. Silica-rich tile

Debris analysis provides the following correlations:

1. Silica-rich tile material originates from Orbiter thermal protection system (TPS). The sample did appear to be heat affected (fused with pumaceous structure).

STS-46 Organic Analysis

Results of the STS-46 Organic analysis indicated the presence of the following materials:

1. Proteinaceous
2. White polymeric
3. Foam-like
4. Rubbery
5. Crystalline
6. Ester-based

Debris analysis provides the following correlations:

1. Proteinaceous material was further evaluated in the laboratory and found to be insect remains and deposits.

2. White polymeric materials were found to include items with cellulosic characteristics, an aromatic polyamide similar to Nylon 4, and calcium carbonate-filled of a probable adhesive origin. These could be products from the protective window covers; evaluation is continuing.

3. Foam-like materials detected were polyurethane and possible Ensolite (modified polyvinylchloride (PVC) with nitrile rubber). Probable sources are not defined at this time, but could include ET insulation and protective window covers.

4. Rubbery materials were identified as an aluminum silicate-filled rubber, a product with silicate and ester characteristics such as Duxseal, and methyl silicone as red RTV. Source of the rubber and Duxseal-like materials is under evaluation. Red RTV is used as a primary bonding product for Orbiter TPS.

5. Crystalline material with an amide characteristic was detected, but a probable source has not been identified

6. Cellulosic fibers originate from the sample cloth used in sampling.

7. Ester-based material appears to be an anti-static agent. The precise source of this item is under evaluation.

Conclusions

The STS-47 mission sustained Orbiter tile damage to a much lesser than average degree. The chemical analysis results from post flight samples did not point to a single source of damaging debris.

Orbiter window samples provided evidence of SRB BSM exhaust, Orbiter TPS, Orbiter window polishing compound, landing site products, organics, and paint. Although the variety of SRB BSM exhaust residuals seemed consistent with previous missions, the variety of Orbiter TPS residuals increased in the different forms of each TPS type, which included: dense tile coatings, silica-rich insulation, silica-aluminum rich insulation and fibers, silica-rich dense coating, and heated tile material with a pumaceous, fused appearance (from the tile sample). The residual variety of earth compounds appeared constant though the results of organic analyses have not yet been completed (reference Figure 19). Included in this report are the results of the STS-46 organic analysis. The immediate laboratory observation was an increase (approximately 50%) in sample material. The results of this analysis are similar to that of STS-50 in that new entries do not appear related to a debris problem.

The lower surface tile (LH outboard elevon) sample provided evidence of only fused-pumaceous tile material. This data is consistent with that observed in previous sampling (reference Figure 19).

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 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 19. Orbiter Post-Landing 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 19. Orbiter Post-Landing Microchemical Sample Results

C-2

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 19. Orbiter Post-Landing 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 materail.
Metallics - includes mostly Aluminum and Carbon Steel alloys

Figure 19. Orbiter Post-Landing Microchemical Sample Results

9.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film review, eleven Post Launch Anomalies, including two IFA candidates, were observed on the STS-47 mission assessment.

9.1 LAUNCH PAD/FACILITY

1. No items.

9.2 EXTERNAL TANK

1. A copper-colored nut or spacer drifted away from the LH2 ET/ORB umbilical area after ET separation from the Orbiter. The origin of this object has not been determined yet.

2. An acreage divot to substrate was visible below the LH2 tank PAL ramp adjacent to the cable tray (XT-1528).

3. A 4-6 inch divot was present in the LH2 tank acreage just below the LH (-Y) bipod spindle/flange.

4. A total of 9 divots occurred in the LH2 tank-to-intertank flange closeout.

5. A 14-16 inch divot occurred in the intertank acreage between the bipods just forward of the LH2 tank-to-intertank flange close out (IFA candidate).

6. A layer of TPS had rolled back on the forward surface of the LO2 ET/ORB umbilical and possible foam damage appeared on the inboard side of the umbilical interface. Foam was also lost from the vertical and horizontal sections of the umbilical cable tray.

9.3 SOLID ROCKET BOOSTERS

1. Pieces of EPON shim were missing from RH SRB aft skirt HDP #3 and #4 prior to water impact (sooted/charred substrate).

2. K5NA was missing from the LH aft booster aft stiffener ring spice plate closeout. Although the K5NA was lost at water impact (clean substrate), examination of the remaining material may have revealed a debonding problem.

9.4 ORBITER

1. EO-3 debris plunger was obstructed by ordnance fragments and had not seated.

2. Drag chute risers damaged three tiles on the vertical stabilizer "stinger". Tile pieces from this damage site were found on the runway along with the drag chute hardware.

3. A 2-4 knot crosswind blew the drag chute somewhat eastward relative to the Orbiter and caused the nose to yaw left (westward). Active steering and braking was required to bring the vehicle back on runway center line. Since this was an unexpected controllability concern, an IFA was taken.

Appendix A. JSC Photographic Analysis Summary

November 3, 1992

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-47 Final Report, and was completed October 21, 1992. Publication numbers are LESC-30462 and JSC-25994-47. 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.

2.0 Summary of Significant Events

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-3, E-17, E-18, E-31, E-57, E-65, E-79, OTV-109, OTV-154, OTV-163)

The usual amount of ice debris from the LO2 and LH2 TSM T-0 umbilicals and the ET/Orbiter umbilicals were noted on many of the MLP camera films. No follow up action is expected.

2.1.1.2 Debris Contacts Left SRB

(Camera E-13)

A small piece of dark debris appeared to contact the left SRB prior to SRB ignition. There appeared to be no damage to the SRB. No follow up action is expected.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris *(Task #7)*

(Cameras E-1, E-2, E-5, E-6 , E-15, E-52, E-60, E-76)

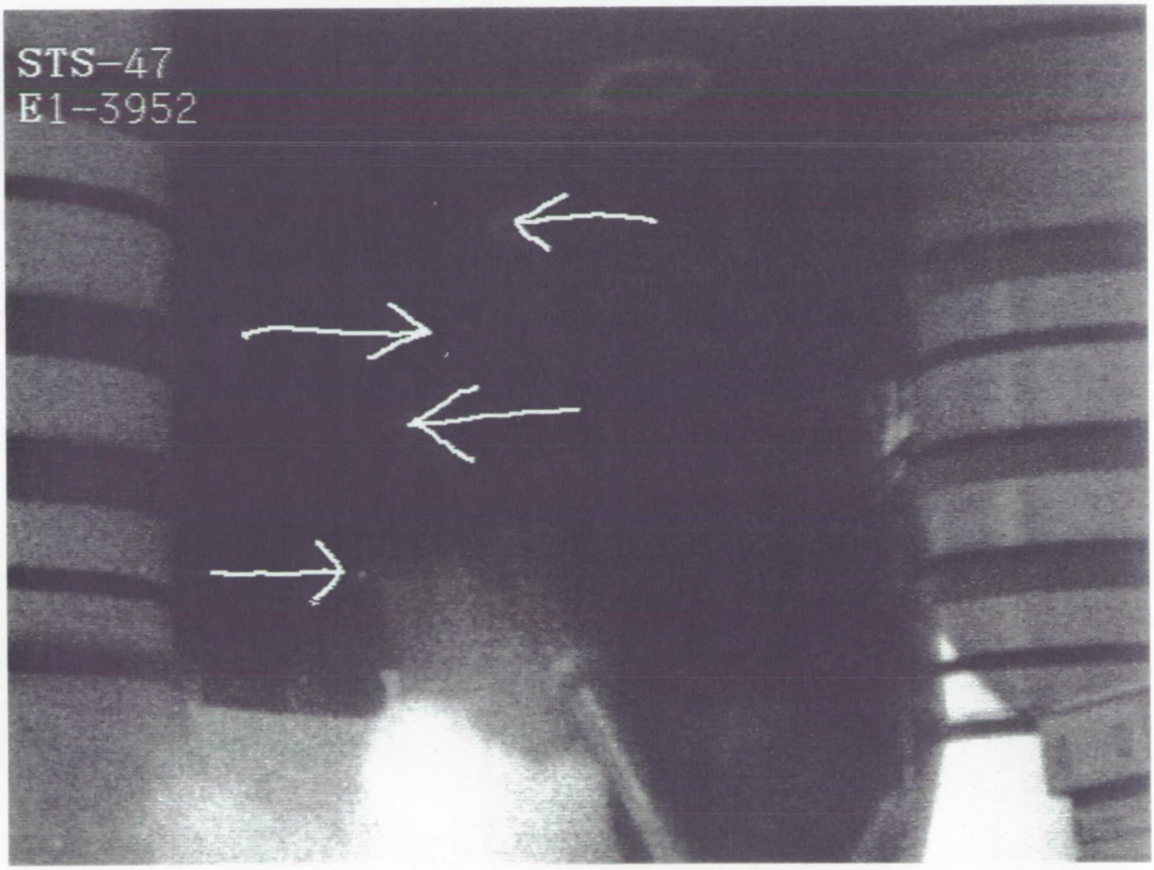


Figure 2.1.2.1 Multiple Pieces of White Debris Seen Exiting Flame Duct

Multiple pieces of white debris were seen exiting from the flame duct at liftoff, move upward, and then appeared to travel above the body flap seen on camera E-1. Some of the debris appeared to be moving toward the Orbiter, but did not appear to strike the vehicle.

Two pieces of debris were observed, one from E-1 and the other from E-5 and E-52, which traveled higher than expected. Upon reviewing the camera E-1, E-5 and E-52 films, it was discovered that the debris observed from camera E-5 was not the same as that seen on E-1 but was the same as seen on E-52. A velocity and trajectory analysis was performed for the two pieces of debris seen on E-52. The highest point reached by either piece of debris on the trajectory was calculated as 15.9 feet which is approximately 11.0 feet below the base of the ET aft dome. The highest velocity reached by either piece of debris was determined to be 18.4 feet per second.

On the camera E-76 film a single large piece of white debris originated from the flame duct and traveled towards the left SRB at SRB ignition.

2.1.2.2 Debris near Holddown Posts

No SRB holddown post stud hang ups were seen on the STS-47 mission films. Less debris than usual was seen near the holddown posts. On camera E-8, a small dark piece of debris was seen near the RSRB holddown post M-2 DCS at SRB ignition. The debris did not appear to contact the vehicle. No follow up action is requested.

2.1.2.3 Large Dark Debris near Left SRB

(Camera E-31)

Figure 2.1.2.3 Large Dark Debris near Left SRB at .20 Seconds MET

A large dark piece of debris, first noted near the left SRB, traveled toward the left inboard elevon at approximately .20 seconds MET and did not appear to strike the vehicle. No follow up action is expected.

2.1.3 Debris after Liftoff

Multiple pieces of debris were seen falling aft of the SLV from liftoff through ascent on the launch tracking views. Most of the debris sightings were probably RCS paper or ice from the ET/Orbiter umbilicals. None of the below-mentioned debris seen after liftoff appeared to strike the vehicle. Debris falling aft of the SLV after liftoff has been seen on films and videos from previous missions. Most of this type of debris has been attributed to ice or RCS paper.

2.1.3.1 SLV Debris at Tower Clear through Roll Maneuver
(Camera E-52, E-54, E-57 , E-59, E-211, E-213,)

Several pieces of white debris were seen falling from the ET/Orbiter umbilical area into SSME exhaust plume just after tower clear.

2.1.3.2 SLV Debris after Roll Maneuver

(Cameras E-57, E-59, E-213, E-222, KTV-4B)

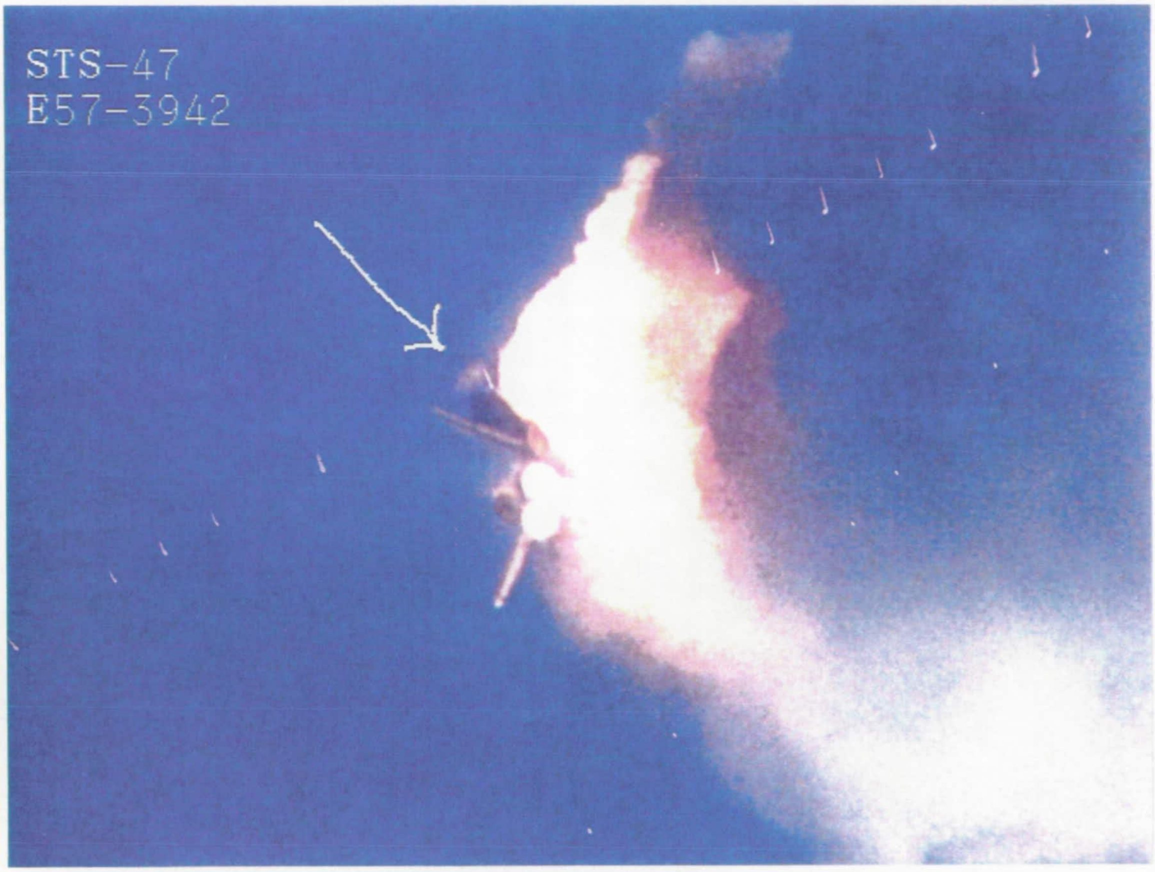


Figure 2.1.3.2a Large Debris Appeared between the Right Wing and the External Tank and Traveled Aft at 29 Seconds MET

ORIGINAL PAGE
COLOR PHOTOGRAPH

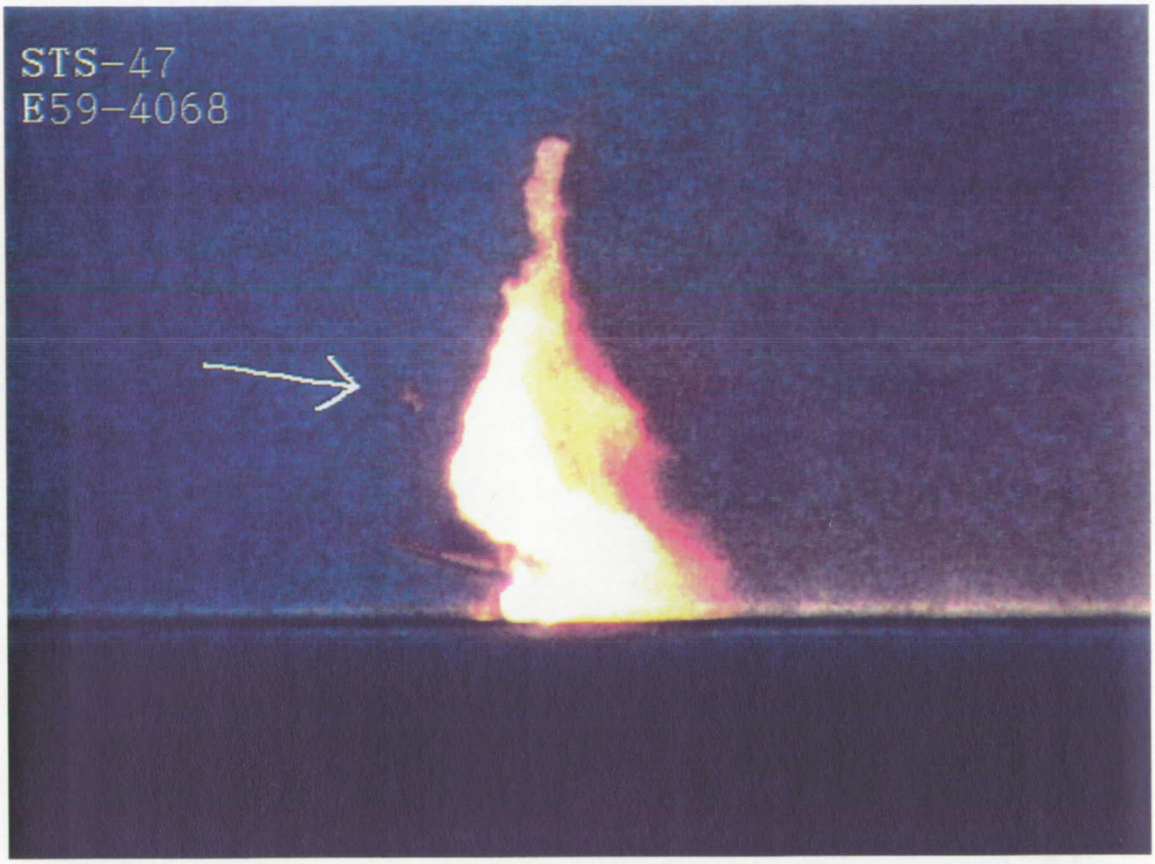


Figure 2.1.3.2b Large Piece of Dark Debris Moving Aft Along the Right SRB Exhaust Plume Boundary at 32 Seconds MET

On camera E-57 a large piece of light colored debris was seen moving towards the right wing and traveled aft at approximately 29 seconds MET (Figure 2.1.3.2a). The object appeared to move towards rather than away from the orbiter/plume area. This indicates that it was probably not vehicle related and may have been a bird. The object did not appear to strike the vehicle.

On camera E-59, a large piece of dark debris was seen traveling aft along the right SRB exhaust plume boundary at 32 seconds MET (Figure 2.1.3.2b). Like the object seen on camera E-57, it appeared to move towards the vehicle and was probably not vehicle related. Again this was probably a bird. The object did not appear to strike the vehicle.

Figure 2.1.3.2c Multiple Pieces of Baggie Material from ET/Orbiter Umbilical Area at 19.4 Seconds MET

On camera E-213 multiple pieces of baggie material were seen to originate from the ET/Orbiter umbilical area and travel aft after the roll maneuver. Approximately 3 seconds later, a piece of orange debris, possibly baggie material, was seen to travel from the RSRB exhaust plume area toward the SSME exhaust plume.

On camera E-222 a single piece of orange colored debris was seen underneath the body flap and then traveled aft of the vehicle at 27.611 seconds MET. At 30.674 seconds MET, multiple pieces of light colored debris were seen originating from behind the SSME area. At 41.578 seconds MET, a light colored piece of debris appeared from behind the vertical stabilizer and fell away from the vehicle.

On camera KTV-4B a piece of white debris was noted aft of the vehicle at approximately 53 seconds MET.

2.2 MLP Events

2.2.1 Orange Vapor

(Cameras E-19, E-76, OTV-170)

Figure 2.2.1 Orange Vapor (Possibly Free-Burning Hydrogen) Noted under the SSME Bells just prior to SSME Ignition

Orange vapor (possibly free-burning hydrogen) was noted under the SSME bells near the southeast TSM hydrogen ignitor nozzle just prior to SSME ignition (T-5.541 seconds). The same orange vapor was also noted near SSME #3 during SSME ignition on the camera E-19 film. The orange vapor appeared to be less extensive than had been noted on previous missions. No further analysis has been requested.

2.2.2 Light Vapor On Inboard Right Wing

(Camera OTV-154)

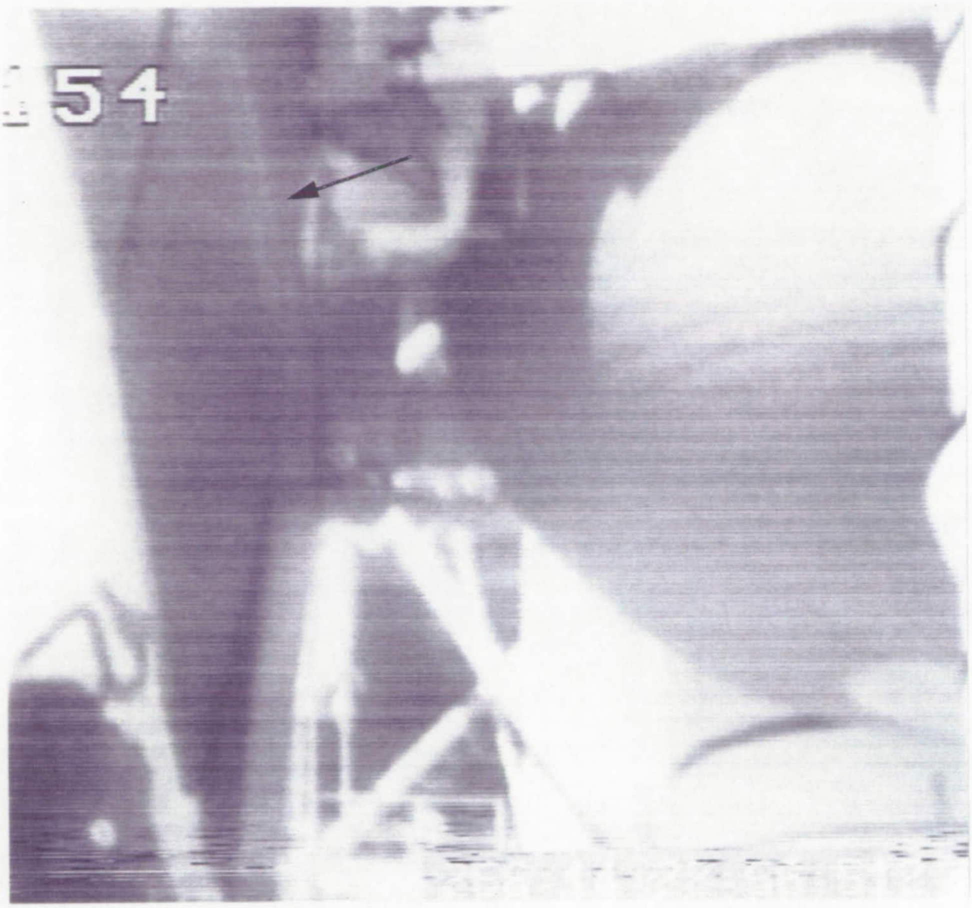


Figure 2.2.2 **Light Mist or Vapor at Junction of the Orbiter Right Inboard Elevon and the Right Wing at T-3.6 Seconds MET**

A light mist or vapor, shown by arrow, was noted at the junction of the Orbiter right inboard elevon and the right wing at SSME ignition (T-3.6 seconds). No follow up action is expected.

2.2.3 Flexing of Base Heat Shield
(Cameras E-77)

A flexing of the base heat shield was noted during SSME ignition. Base heat shield motion was first reported on the STS-49 flight of Endeavour. At that time, an analysis of the base heat shield motion was conducted and it was concluded that the motion is not mission or vehicle specific. A hypothesis is that the motion is caused by pressure waves from the main engines during SSME ignition. No further analysis is expected.

2.2.4 Base Heat Shield Erosion
(Cameras E-17, E-20)

Minor TPS erosion was noted on the left RCS stinger base after SSME ignition on camera E-20 and possible TPS erosion was also seen on the right RCS stinger on camera E-17.

Minor TPS erosion has been seen on previous mission films. No follow up action is expected.

2.0 Summary of Significant Events

2.3 Ascent Events

2.3.1 Flares in SSME Exhaust Plume

(Cameras E-54, E-207, E-222, E-223, KTV-4B)

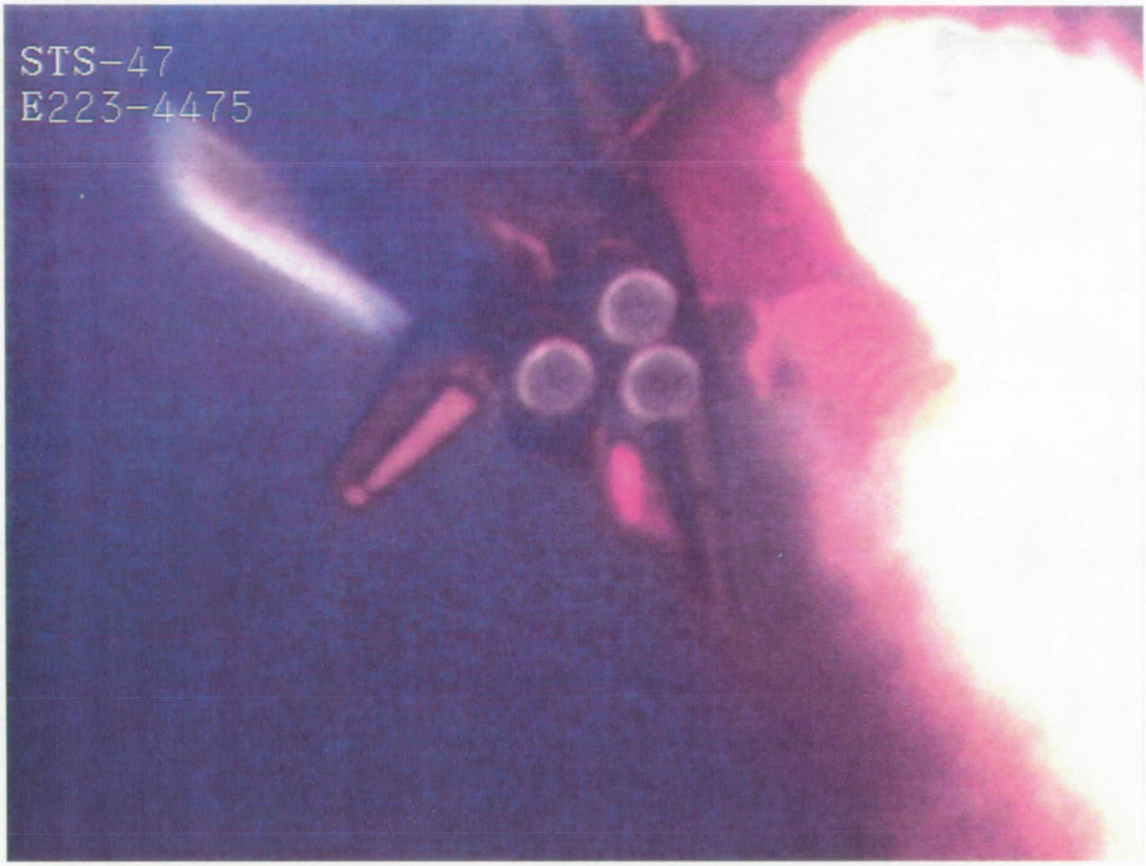
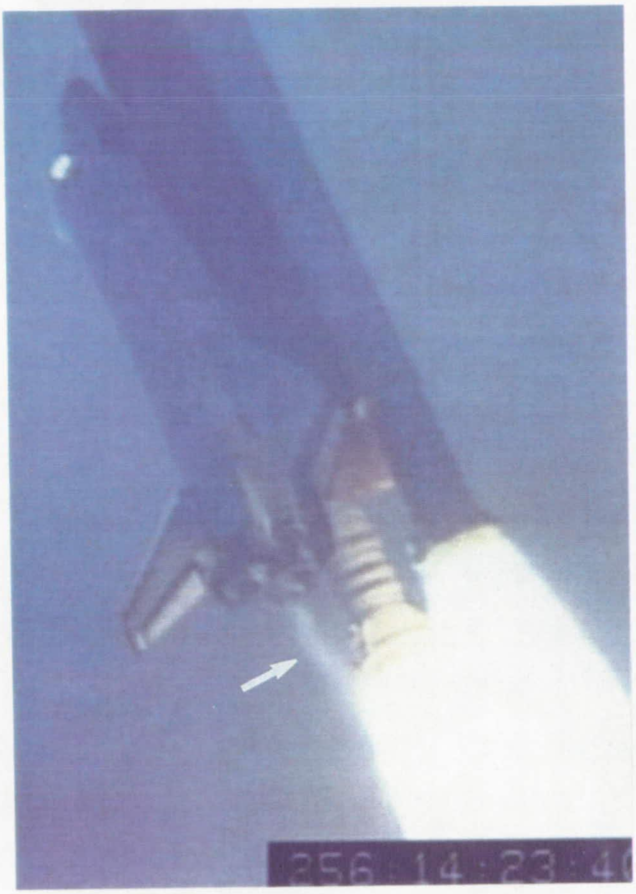


Figure 2.3.1 Flare in SSME Exhaust Plume at 48.7 Seconds MET

Flares were noted in the SSME exhaust plume at 19.8, 45.7, and 48.7 seconds MET. Flares during these time periods have been seen on several earlier missions. No follow up action is expected.

2.3.2 White Streak in SSME Plume at Approximately 40 Seconds MET

(Cameras E-207, ET-207, KTV-4B)



Camera KTV-4B

Camera E-207

2.3.2 Close-up of White Streak at 40 Seconds MET

A white cloud (streak) of vapor was noted in the SSME exhaust plume at approximately 40 seconds MET. The vaporous streak appeared to originate from the right OMS/RCS area of the Orbiter. One possible explanation is that the streak was caused by the atmospheric (moisture) conditions present at that point in the launch trajectory. No follow up action is expected.

2.3.3 Body Flap, Vertical Stabilizer, and Left Wing Motion
(Task #4)
(Cameras E-17, E-207, OTV-163, OTV-171)

Slight body flap motion was seen on cameras E-17 and OTV-163 prior to and at liftoff. On camera OTV-171, a horizontal motion of the vertical stabilizer was noted during SSME ignition. Left wing motion was also noted at liftoff on the camera OTV-163 view. Slight body flap motion was seen on camera film E-207 after liftoff. Body flap, vertical stabilizer and wing motion has been seen on previous mission films. The magnitude of the motion seen on the STS-47 views was not sufficient to warrant further analysis.

2.3.4 Recirculation *(Task #1)*
(Cameras ET-207, E-204, E-205, E-207)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all the previous missions. For STS-47, the start of recirculation was observed at about 92 seconds MET and the end was noted at approximately 105 seconds MET on Camera E-205. See Appendix D for a summary of recirculation start and stop times for all missions since reflight.

<u>Cameras on which recirculation was observed for STS-47</u>

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-207	92	99
E-204	-	-
E-205	92	105
E-207	91	99

NOTE: **Intermittent LOV due to the SRB and SSME plumes prevented acquisition of specific start and stop times for recirculation on camera E-204.**

2.3.5 Orange and Dark Puffs in SRB Plume before SRB Separation

(Cameras E-205, E-220, E-223, KTV-4B, ET-207)

A bright orange puff was noted in the SRB plume at approximately 114 seconds MET. No follow up action is expected.

Figure 2.3.5 Dark Puff in SSME Exhaust Plume

A dark puff was noted in the SRB plume at approximately 116.6 seconds MET (immediately before plume brightening). No follow up action has been requested.

2.3.6 Linear Optical Effect

(Cameras E-204, E-207, E-212, ET-207, E-208, KTV-13)

Linear optical distortions were noted during ascent. On camera ET-207, the linear optical distortions were seen between 67.230 and 99.462 seconds MET. On KTV-13, the linear optical distortions were seen between 65.266 and 104.238 seconds MET.

Linear optical effects have been seen on previous mission views. No follow up action has been requested.

2.4 DTO-0312 Analysis

2.4.1 Analysis of Onboard Umbilical Well Photography *(Task #5)*

2.4.1.1 Debris/Chipping at SRB Separation

Numerous pieces of small debris were seen in the 16 mm umbilical camera film view of the LSRB before, during, and after SRB separation. The debris appeared to be small pieces of TPS that had ablated off the external tank. Multiple divots and chipped areas were visible on the base of the electric cable tray on the umbilical well film. A large piece of TPS can be seen to detach from the electric cable tray approximately 1.8 seconds after SRB separation. A small unidentified dark piece of debris was seen in front of the LSRB just after separation. The aft ET/Orbiter attach brace and the ET aft dome show charring similar to that seen on previous mission umbilical films. The separation of the LSRB appeared normal.

2.4.1.2 Metallic Appearing Object just prior to ET Separation

(16mm Umbilical Well Camera with 5 mm lens)

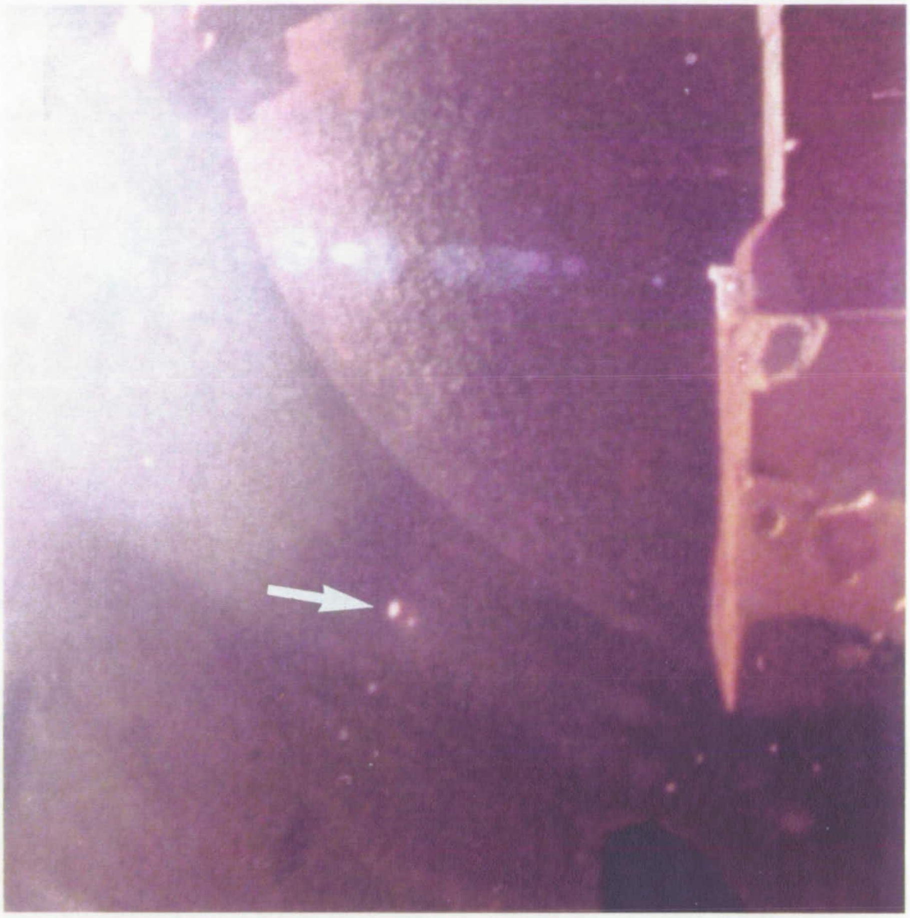


Figure 2.4.1.2 Metallic Appearing Object seen just prior to ET Separation

Upon screening film from the 16 mm camera located in the LH2 umbilical well, a metallic appearing object was observed passing from lower right to left through the field-of-view. The object has not yet been identified. The object is round and squatty in appearance with a hollow appearing center. Enhanced enlarged prints are being developed by the JSC/JL5 Metric laboratory in order to better view this object. Image analysis and menstruation were performed to bound the size and velocity of the debris.

The 16 mm camera is a fixed aperture camera with the focus set at infinity. The metallic appearing debris appeared to be slightly out of focus. If the debris was out of focus due to the object being within the hyper focal distance, an upper bound on the size of the object could be determined. At the hyper focal distance (625 mm), the outside diameter would be 1.07 inches, the inside diameter would be 0.52 inches and the height would be 0.36 inches. If the debris was located between the camera and the ET the upper bound of the object would be 1.68 inches outside diameter, 0.81 inches inside diameter, and 0.57 inches in height. If the debris was outside the ET, the size of the debris may not be determined. The inside to outside diameter ratio was found to be 0.49 while the outside diameter to height ratio was 2.98.

The minimum and maximum velocities, based on the object being within the hyper focal distance or at the hyper focal distance were found be 0.61 and 0.95 feet per second respectively.

A cylindrical piece of debris was previously seen on the LH2 umbilical well camera film on STS-40 and was hypothesized to be a mating guide pin sleeve from the external tank umbilical area. The mating guide pin sleeve has an inside to outside diameter ratio of 0.76 and an outside diameter to height ratio of 1.22 and compared favorably to the debris seen on STS-40 which had a diameter to height ratio of between 1.12 and 1.395. This does not, however, compare favorably with the ratios from the object seen on STS-47 (inside to outside diameter ratio of 0.49 and diameter to height ratio of 2.98). Based on these ratios it does not appear that the debris object from STS-47 is the mating guide pin sleeve or the same piece of debris seen on STS-40.

2.4.1.3 Debris/Ice/TPS Blistering Seen in the ET Separation Sequence
(16mm Umbilical Well Camera with 5 mm lens)

Figure 2.4.1.3 Debris/Ice/TPS Blistering Seen in the ET Separation Sequence

White debris (probably ice) of various sizes and shapes were seen before, during, and after ET separation on the 16mm umbilical camera film (shown by arrow 1). On several occasions, white debris was seen to strike the ET electric cable tray prior to separation. No damage to the electric cable tray was noted. (Two pieces of metallic appearing debris visible on the 16mm umbilical film are described in the following two sections.) A blistered appearance to the TPS on the left side of the LH2 umbilical was visible as the ET began to move away from the Orbiter (see figure 2.4.1.4 arrow 2). Ice was visible in the orifice of the LH2 17 inch line as the LH2 umbilical came into full view (arrow 2). A white marking assumed to be ice was visible to the right of the LH2 umbilical on the ET/Orbiter horizontal attach brace (arrow 3). The view of the LH2 umbilical was reviewed with a lead JSC Propulsion and Power/EP2 and it was concluded that the bushing sleeves appeared to be present in their proper positions (the cylindrical shaped debris object seen on the STS-40 umbilical well film was believed to have been a dislodged bushing sleeve).

2.0 Summary of Significant Events

The events seen in the separation sequence of the external tank have been seen on previous mission umbilical well films with the exception of the metallic appearing debris objects.

2.4.1.4 Clip Shaped Debris at ET Separation

(16mm Umbilical Well Camera with 5 mm lens)

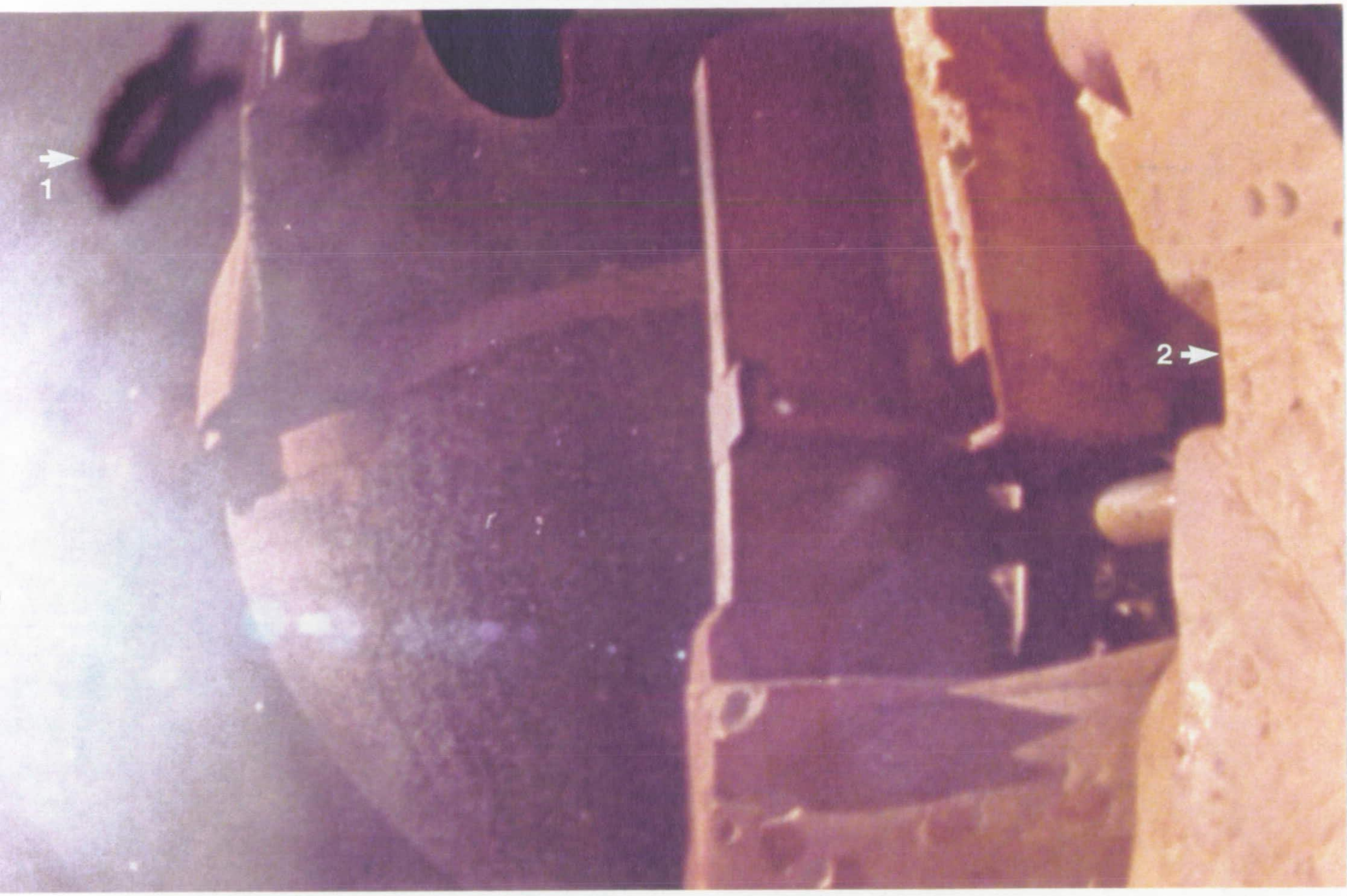


Figure 2.4.1.4 Clip Shaped Debris at ET Separation

A clip shaped object was seen on the film from the 16 mm hydrogen umbilical well camera with the 5mm lens at ET separation (arrow 1). The object first moved to the top of the frame, disappeared for 459 frames and then reappeared. The object then moved downward and disappeared from the FOV. MSFC pointed out that the object appeared to be within the camera housing. The film was rescreened and it was confirmed that indeed the object appeared to be within the camera housing, since the object was seen to pass between the camera lens and the edge of the camera housing.

2.4.1.5 Divots on ET

(35mm Umbilical Well Camera and 70 mm Hasselblad Camera)

Divots were seen on or next to the close-out area between the ET intertank and the LH2 tank extending from the Orbiter side of the ET (+Z) to the left (-Y) and right (+Y) horizons of the external tank. Several divots were seen near the forward ET/Orbiter attach bipod (arrow 1). Shortly after the initial review of the films the divot(s) were declared an inflight anomaly (IFA) by the manager of the JSC Space Shuttle Engineering Integration Office. Divots have been seen near the forward ET/Orbiter attach bipod, along the intertank close-out, and on the intertank TPS on previous mission films. Since reflight, divots in these same regions were reported seen on STS-28R, STS-29R, STS-32R, STS-41R, STS-35, STS-37, STS-40, STS-42, and STS-45 (Reference JSC Space Shuttle Photographic and Television Analysis Project Mission Final Reports). Similar divots were also seen on films from several missions prior to reflight including STS-51F, STS-61A and STS-61C.

Figure 2.4.1.5a Divots near Forward ET/Orbiter Attach Bipod (from the 35 mm Umbilical Well Camera)

Measurements were made of the large divot visible between the legs of the forward bipod located partially on the intertank close-out and partially on the ET intertank TPS using the 35mm umbilical well camera film (Mag 55). The divot measured 0.65 mm x 0.60 mm on the film. Using the known distance between the forward bipod legs of 85.530 inches, the divot was scaled to be 16.35 x 15.09 inches in size. Some shadow is visible inside the divot indicating depth. Under stereoscopic examination, the divot also appeared to have detectable depth. A second divot near the left leg of the forward bipod was measured to be 0.25 mm x 0.25 mm or 6.29 inches in size.

A third divot to the left along the -Y axis on the intertank/LH2 close-out was measured to be 0.25 x 0.4 mm or 6.29 x 10.06 inches in size on the 35 mm film.

Figure 2.4.1.5b Divots seen on ET Intertank (70 mm Handheld Hasselblad Film, Frame STS-47-71-006)

The two divots visible on the intertank close-out and TPS shown on the handheld Hasselblad photograph above taken by astronaut Mark Lee were measured to be approximately 14 inches (left) and 13 1/2 inches (right) in size along their major axis.

2.4.1.6 Marking near LO2 Umbilical Pressurization Line (Orifice)

(35mm Umbilical Well Camera)

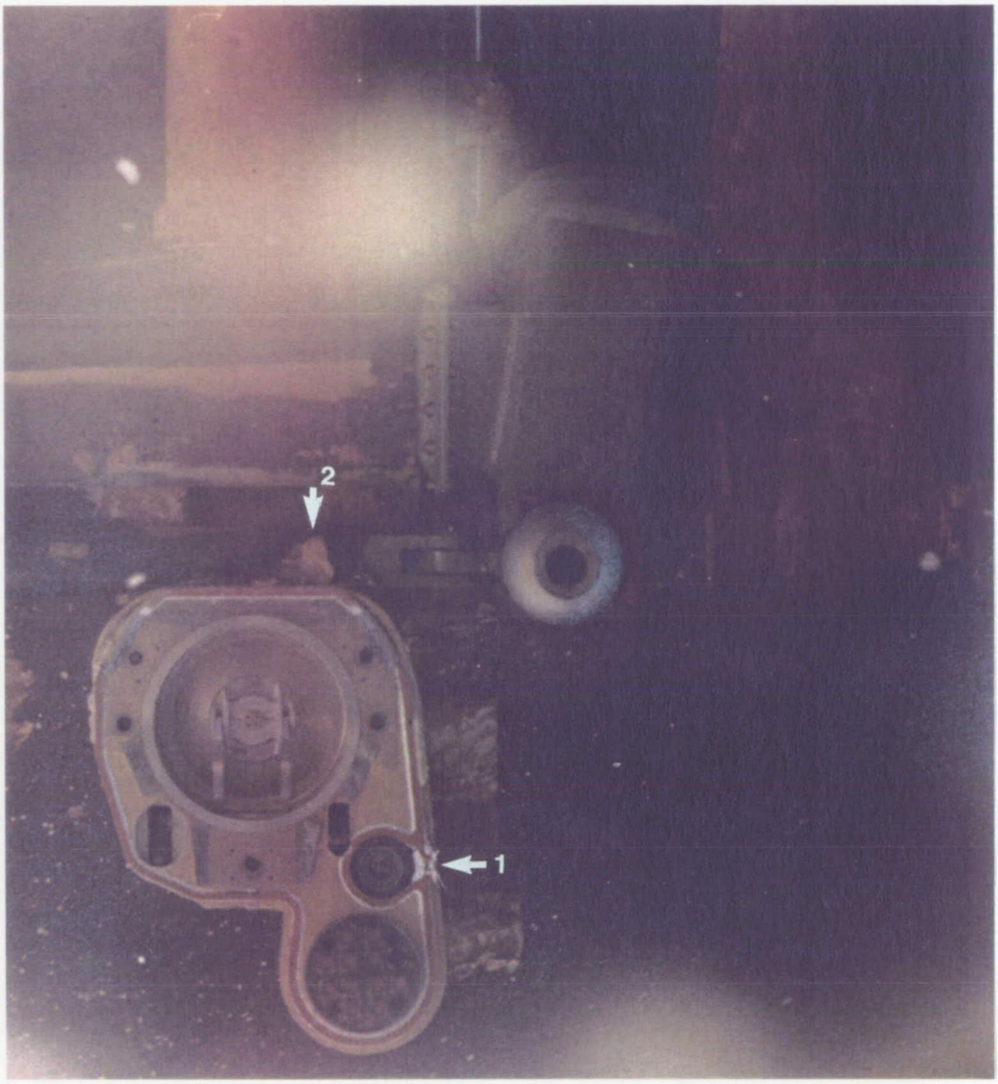


Figure 2.4.1.6 **Marking near LO2 Umbilical Pressurization Line (Orifice)**
(35mm Umbilical Well Camera with mm lens)

A unusual white demarcation and some missing or covered over red border material is visible near the LO2 umbilical pressurization line orifice on the umbilical well 35 mm photograph shown above (arrow 1), this is the same pressurization point where KSC trouble shot a leak prior to flight. KSC stated that the white demarcation is a streaking of RTV caused by the repair to the leak in the pressurization line prior to flight. The image of the demarcation was reviewed with a JSC Propulsion Systems Engineer/EP2 who also believed that the marking and gap in the red border material were a known result of the prelaunch pressure testing. Previous mission umbilical well films have been reviewed and no similar markings were found. No follow up photographic analysis is expected.

2.4.1.7 Possible Loose Insulation above LO2 Umbilical
(35mm Umbilical Well Camera)

A light colored demarcation is visible directly forward of the LO2 umbilical on the 35 mm umbilical well camera film. See figure 2.4.1.6 (arrow 2). The marking appears to be on or laying across the station 2058.0 cross beam. The marking is somewhat triangular in shape and measured approximately 4.8 inches across its longest dimension. This marking could be a loose piece of insulation from the umbilical well. The marking appears similar to the loose insulation from the LO2 umbilical well previously seen on STS-28R umbilical well photography. This event was reviewed with a JSC Propulsion and Power Division engineer. No follow up photographic analysis has been requested.

2.4.2 Onboard Hasselblad ET Analysis *(Task #6)*
(Frames STS-47-71-003 through STS-47-073)

Seventy excellent quality photographs of the external tank were taken by astronaut Mark Lee shortly after ET separation. (See figure 2.4.1.5b for an example of the photography) Method 2 of DTO-312 uses the 70 mm format Hasselblad camera with a 250 mm lens. This was the first flight using the Fuji Velvia 50 color positive film for recording the condition of the external tank. The first picture was taken at 14:36:33 UTC or four minutes and forty seconds after ET separation. The distance of the external tank from the orbiter as measured from the first picture (frame 3) was calculated to be 1,018.3 meters. The last picture was taken at 14:45:46 UTC or thirteen minutes and fifty three seconds after ET separation. The distance of the external tank from the orbiter as measured from the last picture (frame 73) was calculated to be 3,862.86 meters. The separation velocity between the Orbiter and the external tank between the time of the first picture and the last picture was calculated to be 5.14 meters per second. All aspects of the external tank were photographed. Back lighting caused much of the ET surface to be in shadow after the twelfth picture. The tank tumbled from a nose down to a nose up attitude (around the Y axis) in 4 minutes showing the left and right side of the ET. The rotation about the X axis was very slight.

Divots were seen on the ET -Y axis on the intertank/LH2 closeout (see section 2.4.1.5). Other than the intertank closeout divots, the overall condition of the external tank TPS appeared to be in good condition. The ET aft dome showed the typical charring from the ascent heating. The left and right SRB separation burn scars are very apparent on the photography. The burn scars appeared similar to previous mission handheld views. The burn scars did not show conclusive evidence of indications of burning through to bare metal.

2.5 Landing Events

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

2.5.1.1 Landing Sink Rate Analysis Using Film
(Cameras EL-9, EL-12)

Camera EL-9 film was used to determine the sink rate of the main gear. The left inboard tire was used to scale the measurements. Data was gathered from 1.068 seconds prior to landing through touchdown. Three points on every other frame over a period of 100 frames were digitized. These points consisted of the top and bottom of the right tire and a point on the runway immediately beneath the wheel. This raw data was corrected for the vertical change in scale at each frame. The distance between the bottom of the wheel and the runway was computed and a linear regression was applied on this normalized vertical distance vs. time data to find the actual sink rate. This rate was determined to be 0.8 ft/sec. which is well within the current threshold limits.

Nose gear touchdown occurred approximately 17 seconds after main gear touchdown. Camera EL-12 was used to determine the nose gear sink rate. The nose wheel itself was used to scale the measurements. Data was gathered for the 1.595 seconds prior to nose gear touchdown. Three points on every other frame over a period of 76 frames were digitized. These points consisted of the top and bottom of the nose wheel and a point on the runway surface immediately beneath the nose gear. This raw data was corrected for the vertical change in scale at each frame. The distance between the bottom of the wheel and the runway was computed and a linear regression was applied on this normalized vertical distance vs. time data to find the actual sink rate. This rate was determined to be 1.4 ft/sec. which is also well within the current threshold limits.

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

2.5.1.2 Landing Sink Rate Analysis Using Video *(Camera KTV-33)*

Sink rate was calculated for the main gear of the vehicle using a single camera solution. Positional information was acquired by digitizing the landing sequence and then obtaining a screen dump of cursor positions at the points of interest. The positional information was then scaled to actual position and a linear least squares line was fitted through these points as a function of time. The main gear sink rate was calculated to be 1.32 feet per second. A sink rate plot is located in Appendix D Task 3. No follow-up action has been requested. See Appendix D Task #3 for details.

Results from the film analysis are considered better than video because of the higher spatial resolution.

2.5.2 Damage to Base of Vertical Stabilizer

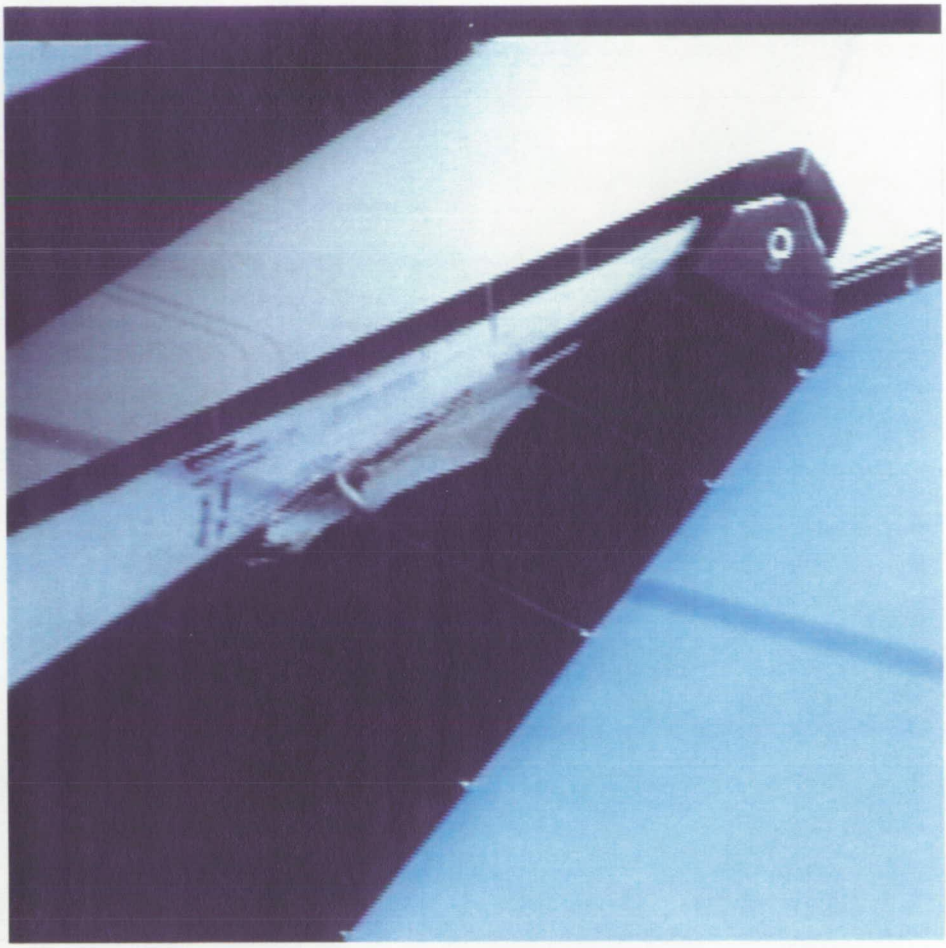


Figure 2.5.2 Damage to Base of Vertical Stabilizer seen at Post Landing Inspection

Damage was noted to the tiles at the base of the left side of the vertical stabilizer near the drag chute door. No follow up action was requested.

2.5.3 Drag Chute Performance *(Task #9)*

The landing of Endeavour at the end of mission STS-47 marked the third deployment of the Orbiter drag chute. All components of the drag chute appeared to deploy as expected. Several tasks were worked in support of the drag chute. A 2-D plot of the drag chute components at deploy was created using video from camera TV-11 (see 2.5.3a). The relative position of the Orbiter as a function of time was calculated to support the analysis of the effect of the drag chute on the vehicle's velocity. Also, the angles of the drag chute with respect to the Orbiter as a function of time were calculated to support the improvement of the aerodynamic math models currently in use.

Relative positional data of selected points on the vehicle and the center of the drag chute were collected from landing cameras EL-7 and EL-9 which were located on the center line of the either end of the runway. The rate at which the film was sampled was approximately 50 frames per second for approximately 13 seconds. Timing information was determined for each frame measured, and angular field-of-view calibrations were performed for each camera. All analysis was performed on each camera individually, and the independent results used for verification purposes. By using the relative position of the vertical stabilizer with respect to the wings and main gear, the orientation of the Orbiter could be determined relative to each camera. This relative orientation information was taken into account during the Orbiter position calculations and the drag chute angle calculations as well.

The positional analysis was performed from the EL-7 and EL-9 data based on the size of the vehicle projected onto the film. The output from these calculations was the distance of the vehicle from each camera as a function of time. (See Figure 2.5.3b).

The changes in the drag chute heading and riser angles with respect to time were determined and are presented in Figure 2.5.3c. The Heading angle is defined as the angle between the drag chute centerline and the Orbiter XZ plane. The Riser angle is defined as the angle between the drag chute centerline and the Orbiter XY plane.

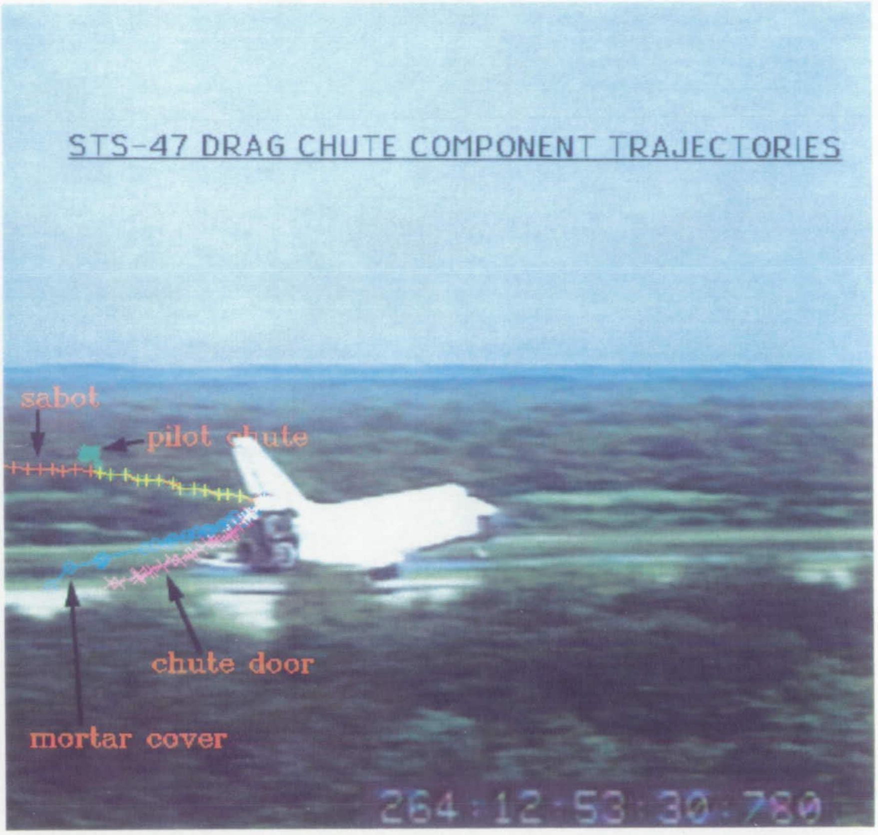


Figure 2.5.3a 2D Plot of Drag Chute Components at Deploy from Camera TV-11

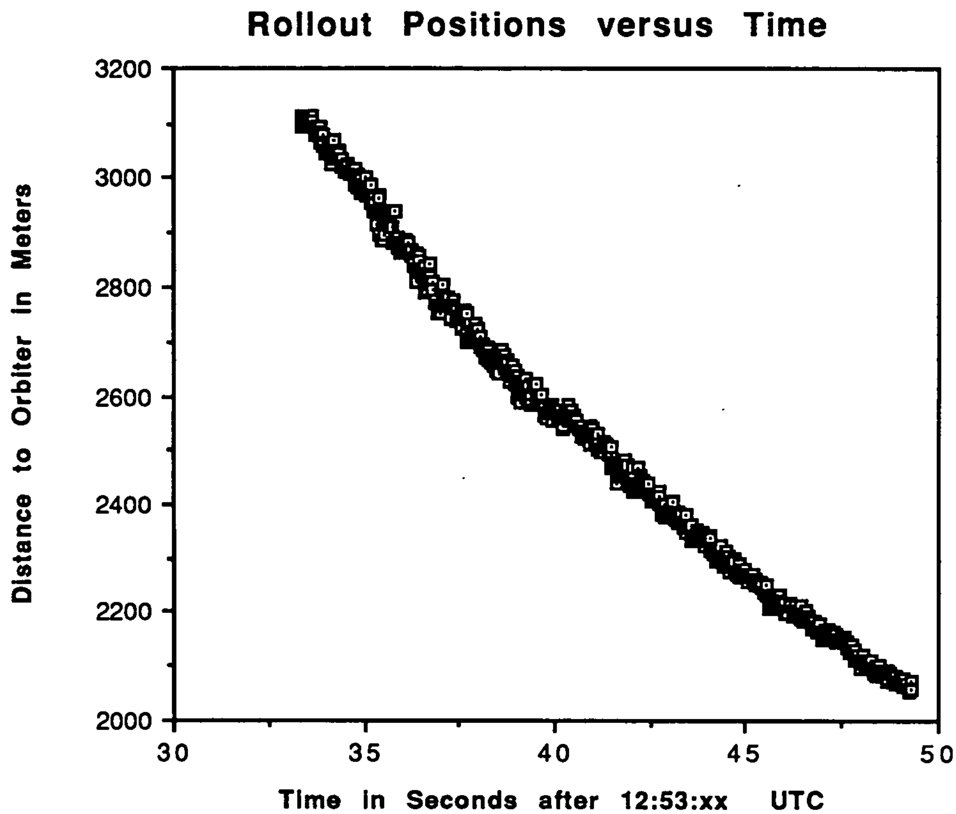


Figure 2.5.3b Distance of Endeavour from Camera EL-7 as a Function of Time

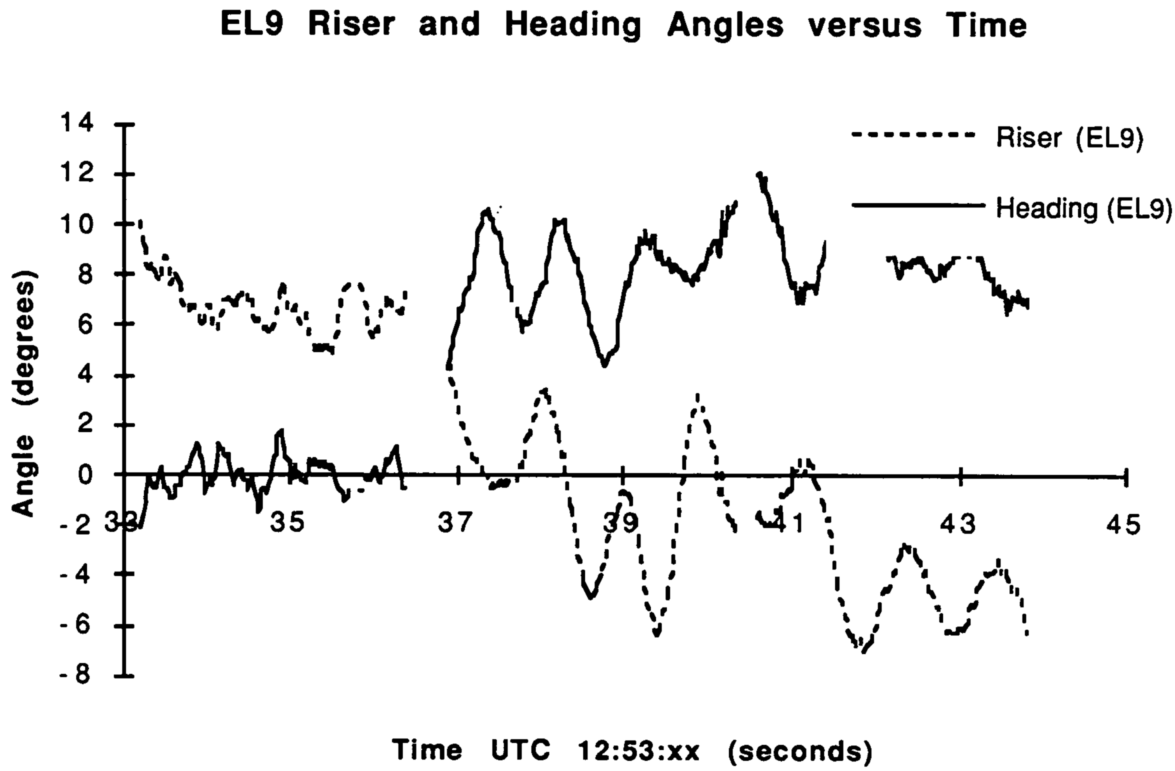


Figure 2.5.3c **Change in Drag Chute Riser & Heading Angles with respect to Time** (Gaps in the data are caused by visual obstructions)

2.6 Other Normal Events

Other events seen on the STS-47 launch views that have been seen on previous shuttle flights include: smoke from the hydrogen ignitors during startup; RCS paper in SSME plume at startup; frost buildup around the umbilical baggie area and the ET vent louvers; normal pad debris; butcher paper debris from the RCS ports; multiple pieces of MLP debris in the exhaust plume after liftoff; ET aft dome outgassing; vapor from both SRB stiffener rings; acoustic waves during liftoff; RCS paper and normal debris seen during roll maneuver; overshoot of the roll maneuver; RCS paper debris in the SSME plume after roll maneuver; expansion waves after roll maneuver; slight charring of the ET aft dome; flares in SRB plume; condensation around the SLV; SRB exhaust plume brightening at tail off; and slag noted after SRB separation.

Appendix B. MSFC Photographic Analysis Summary

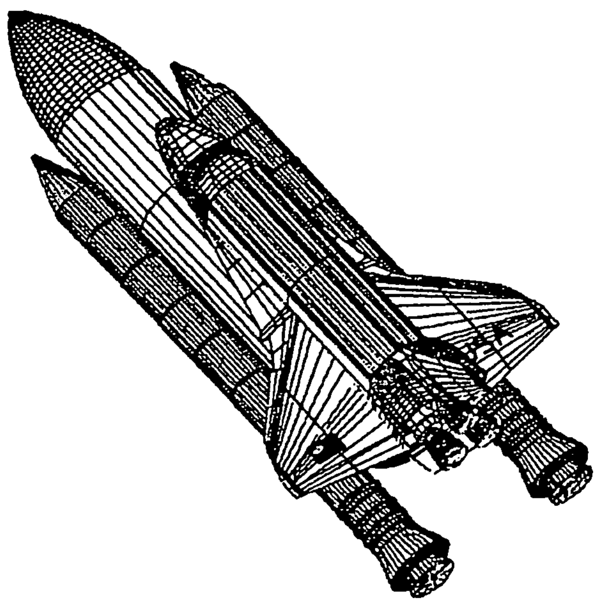
National Aeronautics and
Space Administration

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

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-47



MSFC - Form 454 (Rev. October 1976)

STS-47 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-47

FINAL

PREPARED BY:

J. HIXSON, D. BUSING, B. VIGER, W. LANGLOIS
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:

JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

APPROVED BY:

T. RIECKHOFF, MSFC/EP53
B. LINDLEY-ANDERSON, MSFC/EP53

October 14, 1992

I. INTRODUCTION

Space Shuttle Mission STS-47, the second flight of the Orbiter Endeavour was conducted September 12, 1992 at approximately 9:23 A.M. Central Daylight Time from Launch Complex 39B (LC-39A), 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-47 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-eight of fifty-eight requested cameras as well as video from twenty-four of twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-47.

CAMERA DATA RECEIVED FOR STS-47

	16mm	35mm	70mm	Video
MLP	24	0	0	4
FSS	7	0	0	3
Perimeter	3	3	0	6
Tracking	0	16	0	11
Onboard	3	1	1	0
Totals	37	20	1	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-47 was considered good. Coverage from the trackers was limited due to haze and cloud coverage. Camera E-8 timing block is dark but readable. On camera E-16 the field of view is bad and the timing information block is erratic. Camera E-34 the timing is suspect. Cameras E-52 and E-220 experienced some camera jitter.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly. However, camera E-301 did not record water impact. Also, the astronauts carried a 70mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. One 16mm motion picture camera and one 35mm still camera were flown on this mission in the Orbiter's umbilical well to record the SRB and ET separation events.

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" disconnect and umbilicals and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors, purge barrier material and SRB thermal curtain tape.

b. ET TPS Divots:

Seventy-three film frames were captured of the external tank. Figure one is a film frame showing two divots noted at LH2 intertank scarf joint (-Y +Z quadrant) and one large divot between the bipod strut. An analysis was performed on the large divot by overlaying the 3-D CAD geometry on the image. This divot is approximately 17 x 21 inches with an area approximately 350 sq. inches.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times were 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	256:14:23:00.018
M-2	E-8	256:14;23:00.019
M-5	E-12	256:14:23:00.018
M-6	E-13	256:14:23:00.017

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 31.8 inches. Figure two 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-47 was determined to be 256:14:25:04.13 UTC taken from camera E-207.

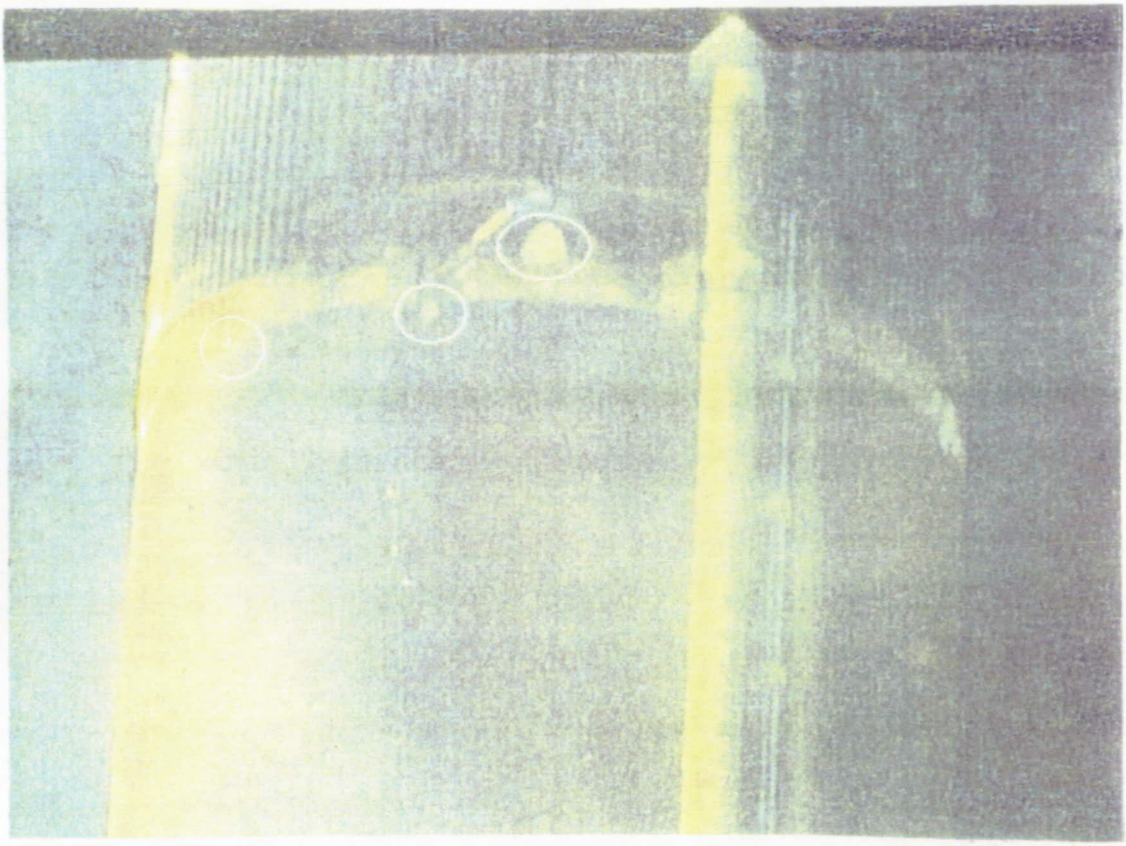

Figure One

Divots Noted at LH2 Intertank Scarf Joint and Bipod Strut

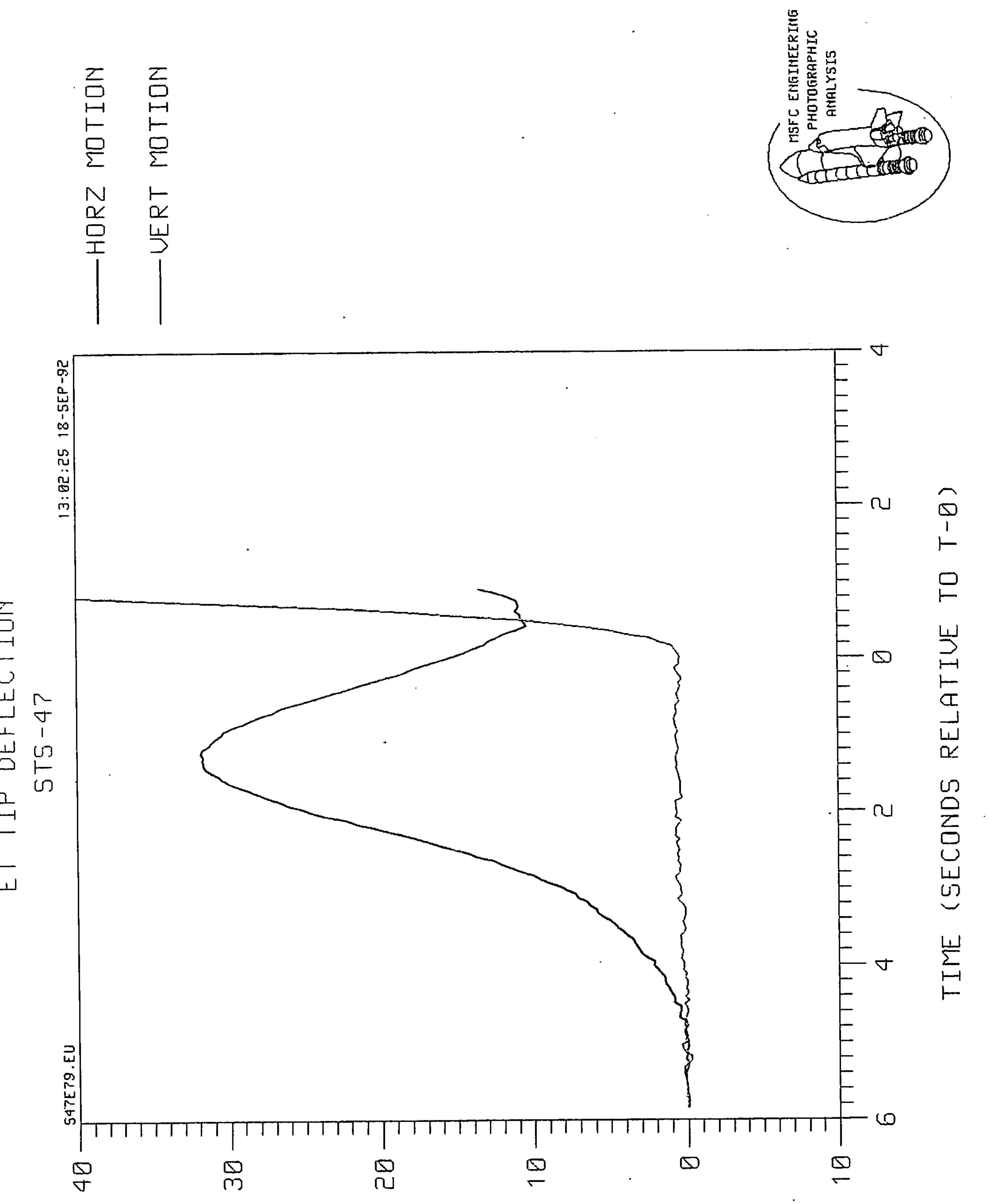
ET TIP DEFLECTION
STS-47
HORZ MOTION
VERT MOTION
MSFC ENGINEERING PHOTOGRAPHIC ANALYSIS
13:02:25 18-SEP-92
S47E79.EU
TIME (SECONDS RELATIVE TO T-0)
MOTION (INCHES)
40
30
20
10
0
10
6
4
2
0
2
4

Figure Two

Appendix C. Rockwell Photographic Analysis Summary

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

Rockwell International

August 19, 1992

In Reply Refer to 92MA3490

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-50 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 39A Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-50 launch conducted on June 25, 1992, at approximately 9:12 AM (PDT) from the Kennedy Space Center (KSC) and for the landing on July 9, 1992 at KSC (4:43 AM PDT).

Rockwell received launch films from 84 cameras (61 cine, 23 video) and landing films from 18 cameras (11 cine, 7 video) to support the STS-50 photographic evaluation effort. Two films, E-57 and E-77, were not available due to camera malfunctions.

All ground camera coverage for this mission including coverage on the MLP, FSS and tracking cameras were good. However, due to the accumulation of clouds, many of the tracking video and films reviewed were obstructed after the vehicle went through the cloud cover. This hampered analysis and possible detection of debris and/or anomalies.

Overall, the films showed STS-50 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. No vapor was observed in the vicinity of the rudder/speed brake at liftoff. Charring of the ET aft dome and recirculation were not visible due to heavy cloud cover. Booster Separation Motor (BSM) firing and SRB separation appeared normal but could only be verified by one camera due to the cloud cover.

(Packing Sheet No. DM92-17888)

A disturbance in the lateral acceleration strip chart data at liftoff led Rockwell Engineers (Ascent Separation Systems) to suspect there had been a bolt hang-up on one of the SRB holddown support posts. This assumption was confirmed when films E-7 and E-10 were reviewed which clearly showed the post M-4 bolt to hang-up at liftoff. The bolt also deflected during liftoff until the aft skirt foot rose sufficiently to release it, causing the bolt to spring back to its original vertical position.

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 GH2 vent line carrier dropped normally and latched securely with no rebound. No anomalies were identified with the ET/ORB LH2 umbilical hydrogen dispersal system hardware.

STS-50 was the eigth 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. Significant events that were seen include a bolt hang-up at holddown post M-4 of the right SRB at liftoff and a dark piece of flexible debris which originated from the right SRB flame duct and moved north away from the vehicle. These events and other events noted by the Rockwell film/video users during the review and analysis of the STS-50 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. A hangup of the holddown post M-4 holddown bolt on the SRB was seen at liftoff on cameras E-7 and E-10. Rockwell/Downey engineers had previously reported a disturbance in the lateral acceleration strip chart data at liftoff which led them to expect a possible holddown post bolt hangup. This event was clearly seen in the photographic review as the M-4 holddown bolt rose a significant amount during liftoff before breaking away from the SRB and springing back into position. No further analysis is planned.

2. On Camera E-7 a large piece of EPON shim material debounded from the holddown post M-4 aft skirt foot and fell into the flame duct during liftoff. This is probably caused by the M-4 bolt hangup. No further analysis is planned.

3. Orange vapor (possibly free burning hydrogen) was seen below the SSME's just prior to SSME ignition on cameras E-3, E-5, E-15, E-17, E-18, E-19, E-20, E-23, E-62, E-63, E-76 and beneath the body flap (moving north) on camera's OTV-063, OTV-070, and E-30. 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.

4. Flexing (an up and down motion) was noted in the base heat shield in the centerline area between the SSME cluster during the early stage of SSME ignition. Base heat shield movement has occurred on previous missions and no follow-up action is planned.

5. On cameras E1, E4 & E15 a large piece of flexible debris originated from the RSRB flame trench shortly after SRB ignition. Does not appear to strike vehicle. No further analysis planned.

6. On camera E-18, Two pieces of debris (origin unknown) fall aft from above the left inboard elevon prior to liftoff. Does not appear to strike vehicle.

7. Orange flares and flashes seen in the SSME plumes (E2, E3, E52, E213, E222, E223). These observations are seen frequently and are understood to be burning of propellant impurities including RCS paper covers. No follow-up action is planned.

8. During the screening of the 16mm and 35mm umbilical well camera films an apparent rectangular shaped divot was seen on the LH2/intertank flange at the base of the left leg of the forward ET/Orbiter attach bipod. The forward bipod is in the standup position. Several small divots or chipping of the TPS was seen near the LO2 feed line, LO2 umbilical and the forward ET/Orbiter attach. Blow-ups of the ET 16mm & 35mm film is underway and analysis is in progress.

9. The following events have been reported on previous missions and observed on STS-50. These are not of major concern, but are documented here for information only:
    - Ice debris falling from the ET/Orbiter Umbilical disconnect area.
    - Debris (Pad, insta-foam, water trough) in the holddown post areas and MLP.
    - 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.
    - Shock waves visible on the pad at SSME startup.
    - Debris pieces in the SSME/SRB plumes.
    - Condensation around the SLV after the roll maneuver.
    - ET aft dome outgassing and charring.

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-E28 - OMRSD File IX Vol. 5, Requirement No. DV08P.020 requires an analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.

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

12. The landing of STS-50 occurred on runway 33 at the KSC Shuttle landing facility. Good video and film coverage of the drag chute deploy was obtained. The drag parachute system performed as expected. All sequenced events occurred as planned and no hardware anomalies were observed.

    Analysis continues in the areas of compartment door trajectory, reeled main chute operation, and riser position relative to the Orbiter stinger. The results of this analysis will be used to validate models against actual flight data, and to allow accurate predictions for future flights.

This letter is of particular interest to W. J. Gaylor (VF2) and J. M. Stearns (WE3) at JSC. The Integration Contractor contacts are R. Ramon at (310) 922-3679 or C. I. Miyashiro at (310) 922-0214.

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A Debris/Ice/TPS assessment and integrated photographic analysis was conducted for Shuttle Mission STS-47. 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-47, and the resulting effect on the Space Shuttle Program.

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