NASA Technical Memorandum TM 107554

Debris/Ice/TPS Assessment And Integrated Photographic Analysis For Shuttle Mission STS-52

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National Aeronautics and
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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-52

October 22, 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-52 was launched at 1:09 p.m. local 10/22/92

1.0 Summary

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 21 October 1992. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (13th flight), ET-55 (LWT 48), and BI054 SRB's. There were no vehicle or facility anomalies.

The vehicle was cryoloaded for flight on 22 October 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 leakage during the cryoload. No unusual vapors or cryogenic drips were visible during tanking, stable replenish, and launch. An 8-inch long dogleg crack was present in the forward surface TPS covering 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 a stress relief cut had been eliminated by design at the factory. The condition was acceptable for launch per NSTS-08303 and CR S041254C.

Leak detectors #23 and #25 located within the GUCP cavity indicated the presence of a hydrogen leak external to the vent line from cryogenic loading slow fill through stable replenish. Readings peaked during vent valve open cycles. The leak reached a maximum value of 44,000 ppm thirty minutes into topping then remained at 20-30,000 ppm during replenish. The suspected area of leakage was at the tank side teflon seal, which mates with the 7-inch GH2 vent quick disconnect probe. More than usual amounts of ice and frost covered the uninsulated areas of the GUCP around the 7-inch line. Post launch inspection and retest of the GSE hardware did not reveal any anomalies.

A debris inspection of Pad 39B was performed after launch. No flight hardware was found with the exception of one FRSI plug. EPON shim material on the south holddown posts was intact but slightly debonded on the HDP #1 and #2 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. A preliminary inspection of the GUCP 7-inch line sealing surface was performed in an effort to determine the cause of the hydrogen leak detected during cryogenic loading. No obvious discrepancies were noted. Post launch disassembly and retest of the hardware also revealed no anomalies. A dimensional analysis of the bellows is still in work, but the IPR documenting the condition will most likely be closed as an Unexplained Anomaly (UA). Damage to the facility overall was minimal.

A total of 134 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. GUCP disconnect from the External Tank was nominal. There was no external evidence of the hydrogen leak at the 7-inch QD. On-orbit imagery from the ET/ORB umbilical cameras and the flight crew handheld photography revealed nominal SRB and ET separations. A section of the red purge seal was missing from the aft inboard corner of the LH2 umbilical. This section of material adhered to the Orbiter side of the umbilical interface and was still attached after Orbiter landing. A 5-inch divot to substrate was present in the LH2 tank acreage at XT-1399 adjacent to a previously sanded area. Some of the left bipod jack pad TPS closeout was missing. Foam was also missing from the aft outboard corner of the LH bipod ramp closeout. A possible divot may have occurred in the LH2 tank-to-intertank flange closeout just aft of the LH bipod spindle. Otherwise, there were no divots in the flange closeout -Y+Z and +Y+Z quadrants where divots have typically occurred on previous tanks. At least 20 small pieces of TPS were missing from intertank stringers forward of the LH2 tank-to-intertank flange/bipod area. No metal substrate/primer was visible. Film analysis also showed orbiter performance, landing gear extension, wheel touchdown, and vehicle rollout after landing were normal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The RH frustum had 18 MSA-2 debonds over fasteners and one 1.5-inch diameter area of missing TPS in the -Y+Z quadrant. The LH frustum was missing no TPS but had 27 MSA-2 debonds over fasteners. The RH forward skirt was missing no TPS but did have two acreage debonds. All Debris Containment System (DCS) plungers were seated properly. Pieces of EPON shim were missing from HDP #3 and HDP #8. The material was lost prior to water impact (sooted/charred substrate).

A detailed post landing inspection of OV-102 was conducted on 1 November 1992. The Orbiter TPS sustained a total of 290 hits, of which 16 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 152 hits, of which 6 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of Orbiter TPS debris hits was much greater than average and the number of hits one inch or larger was less than average. All three ET/Orbiter separation devices (EO-1, 2, and 3) and all ET/ORB umbilical separation ordnance retention shutters functioned properly. No flight hardware was found on the runway below the umbilicals when the ET doors were opened.

The majority of tile V070-395093-016 was missing from the base heat shield between SSME #2 and #3. This tile, which covers a calorimeter, sustained an in-plane failure, leaving the strain isolation pad and an attached layer (approximately 0.3 inches thick) of densified tile material in the cavity. An In-Flight Anomaly (IFA) was taken. In addition to the missing tile, an 8 by 6 by 0.5-inch tile damage site was present on the base heat shield adjacent to SSME #1 (at approximately the 7:00 o'clock position). This damage site appeared to have been caused by a dense object and may have been caused by the lost tile. This flight marked the fourth use of the Orbiter drag chute. The drag chute appeared to have functioned nominally. All drag chute hardware was recovered and showed no signs of abnormal operation. The only unexpected flight hardware found on the runway was a tile gap filler from the aft fuselage sidewall.

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. HRSI tile damage site samples revealed only the presence of Orbiter TPS materials, although a new type of TPS coating residue was detected. This residual sampling data does not indicate a single source of damaging debris as all of the other materials have been documented previously in post-landing sample reports. The residual sample data also gave no indication of debris trends when compared to previous mission data.

A total of ten Post Launch Anomalies, but no IFA candidates, were observed during the STS-52 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Debris/TPS/Photographic Analysis Team briefing for launch activities was conducted on 21 October 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
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
J. Cawby	LSOC - SPC	Supervisor, ET Processing
J. Blue	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
M. Dean	LSOC - SPC	ET Processing
W. Richards	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
M. Nowling	MTI - LSS	SRM Processing
R. Kretz	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.

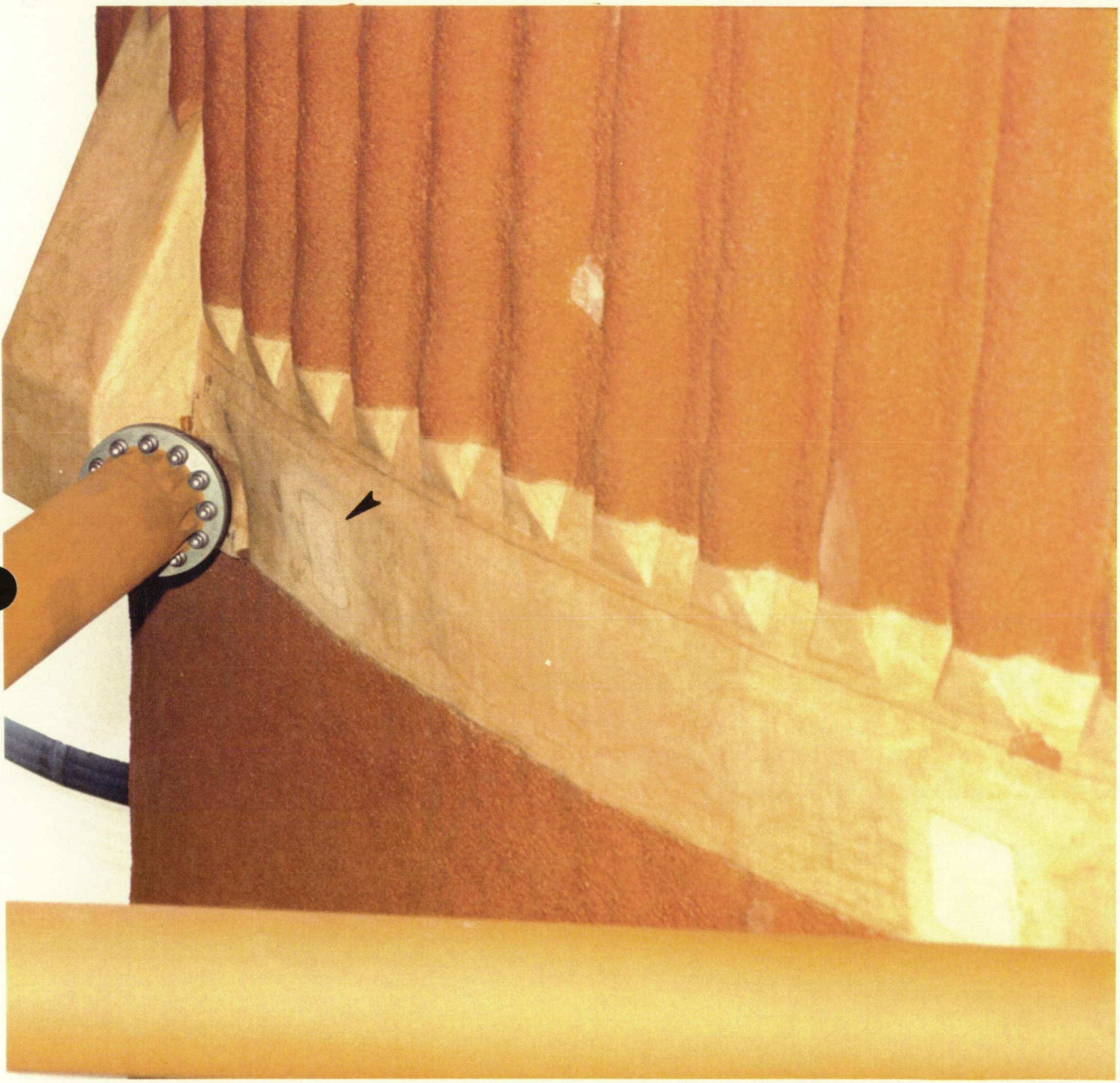
2.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 21 October 1992 from 0930 - 1030 hours. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (13th flight), ET-55 (LWT 48), and BI054 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

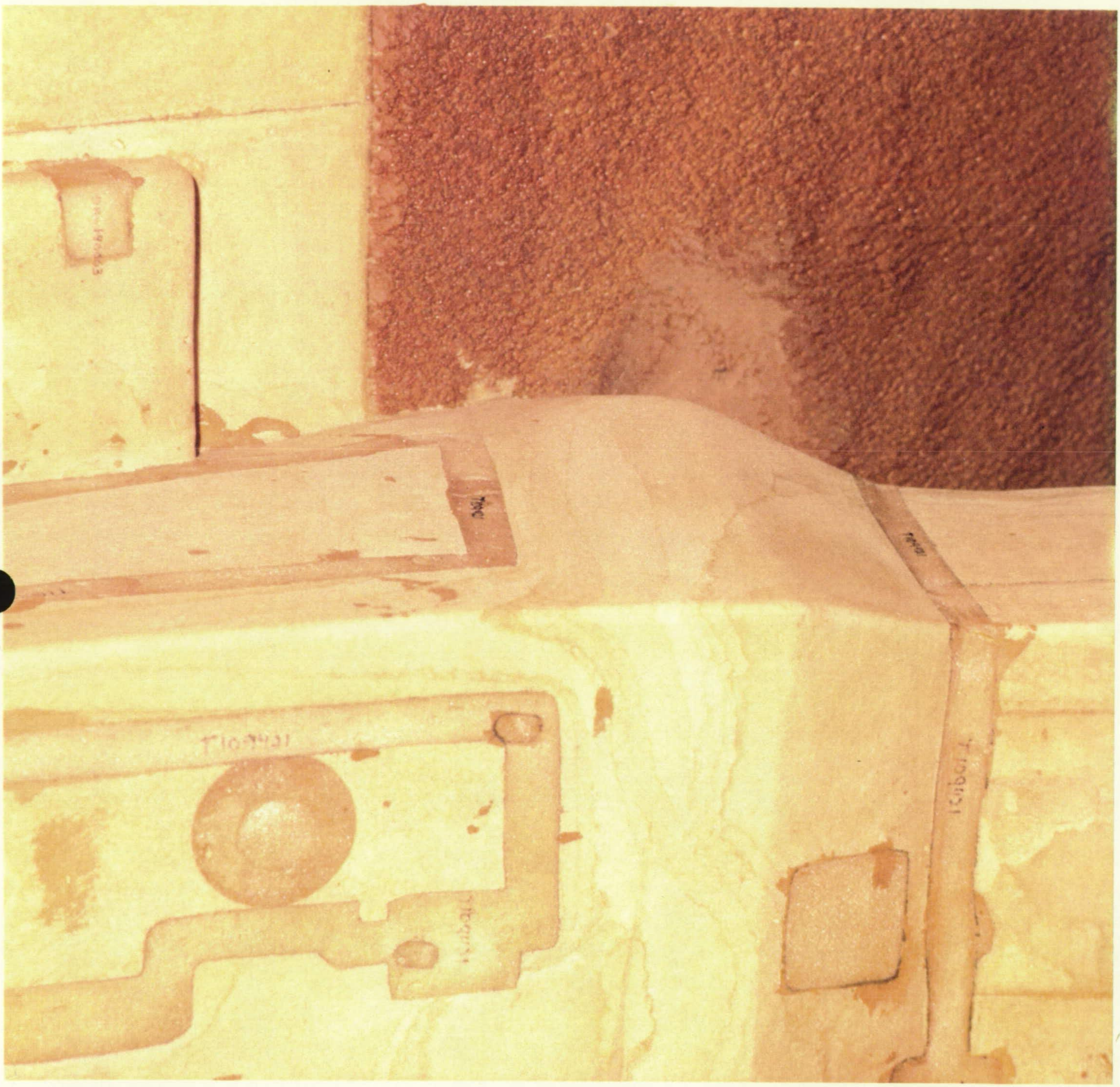
Due to the continued concern over potential hydrogen leakage from the ET/ORB LH2 umbilical interface area during cryoload and launch, tygon tubes for hydrogen leak detectors LD54 and LD55 were installed at the LH2 ET/ORB umbilical. The tygon tubes are intended to remain in place during cryogenic loading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

There were no significant vehicle anomalies.

There were no vehicle or facility debris issues. The MLP deck and areas under the raised decks were swept again prior to launch to remove small debris items, such as sand, rust flakes, and paint chips. 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 LH bipod jack pad 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.

3.0 LAUNCH

STS-52 was launched at 17:09:39.063 GMT (1:09:39 p.m. local) on 22 October 1992.

3.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 22 October 1992 from 0620 to 0800 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:	72.6 Fahrenheit
Relative Humidity:	54.9 %
Wind Speed:	15.1 Knots
Wind Direction:	049 Degrees

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

3.2 ORBITER

No Orbiter tile or RCC panel anomalies were observed. 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, but the base heat shield tiles were dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

3.3 SOLID ROCKET BOOSTERS

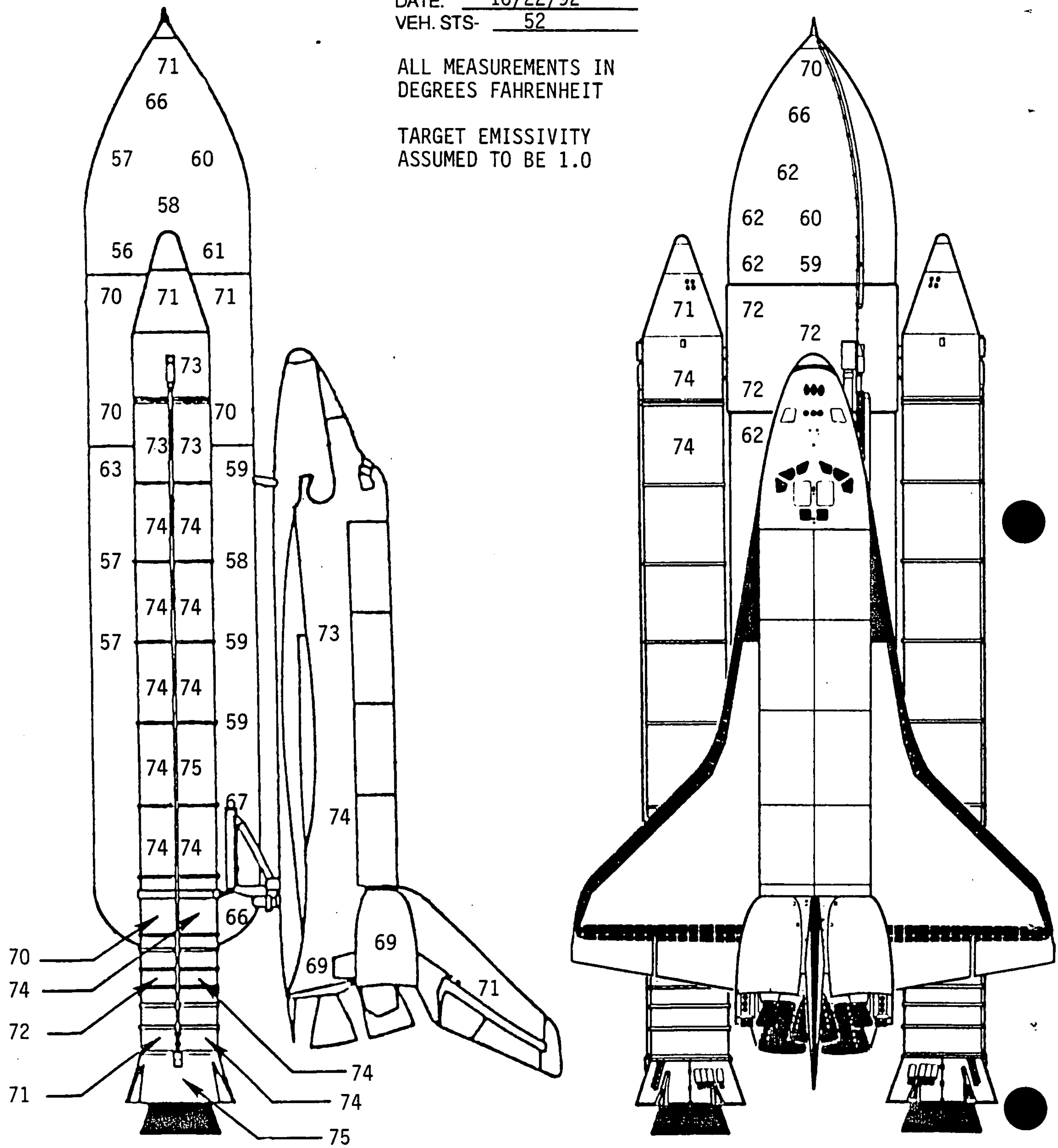
No SRB anomalies or loose ablator/cork were observed. The K5NA closeouts of the aft booster stiffener ring splice plates were intact. The STI portable infrared scanner recorded RH and LH SRB case temperatures between 68 and 75 degrees Fahrenheit (F). In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer ranged from 67 to 75 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures ranging from 72 to 75 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 78 degrees F, which was within the required range of 44-86 degrees F.

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

TIME: 0620 - 0800 EST
DATE: 10/22/92
VEH. STS- 52

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



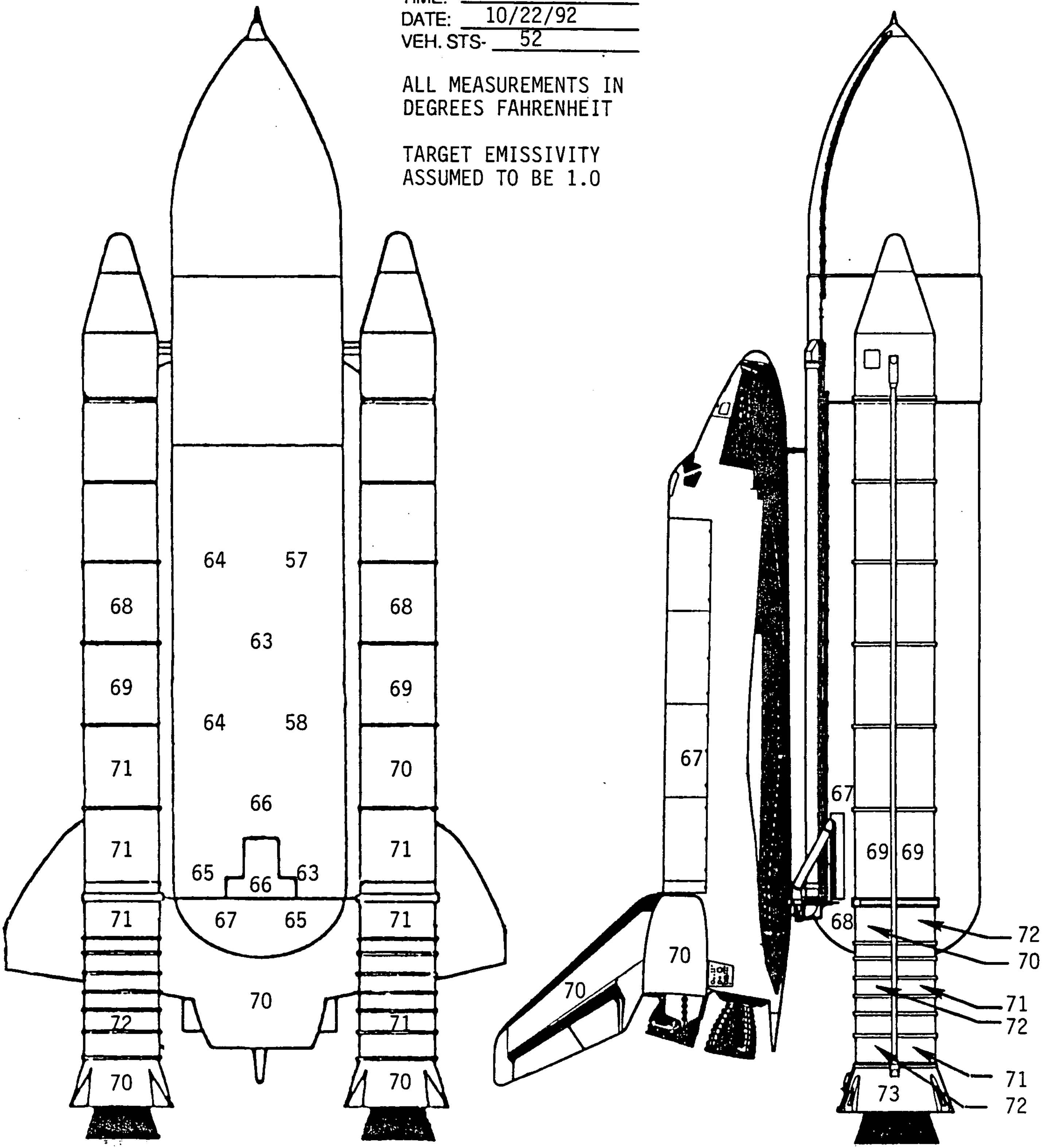
EGG/V-343D

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

TIME: 0620 - 0800 EST
DATE: 10/22/92
VEH. STS- 52

ALL MEASUREMENTS IN DEGREES FAHRENHEIT

TARGET EMISSIVITY ASSUMED TO BE 1.0



EGG/V-343C

3.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0445 to 1245 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 no condensate or 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 portable STI measured surface temperatures that averaged 68 degrees F on the ogive and 60 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 65 degrees F on the ogive and 61 degrees F on the barrel; SURFICE predicted temperatures of 60 degrees F on the ogive and 55 degrees F on the barrel.

The intertank acreage TPS was dry. No frost spots appeared in the stringer valleys at the LH2 and LO2 tank-to-intertank flanges. More than usual ice/frost accumulations, but no unusual vapors, were present on the ET umbilical carrier plate. Both the portable STI and the Cyclops radiometer measured an average surface temperature of 71 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 60 degrees F on the upper LH2 tank and 65 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 61 degrees F on the upper LH2 tank and 67 degrees F on the lower LH2 tank; SURFICE predicted temperatures of 56 degrees F on the upper LH2 tank and 61 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.

An 8-inch long dogleg crack was present in the forward surface TPS covering of the -Y vertical strut cable tray near the longeron closeout interface. The 3/8-inch wide 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.

STS- 52	TEST S0007 LAUNCH	DATE: 10 October 1992	T-0 TIME: 13:09:40 DATE: 10/22/92	NASA KSC Ice/Frost/Debris Team
ORBITER 103 / ET 55 / SRB BI-054 / MLP 3 / PAD B	LO2 CHILLDOWN TIME: 03:00 SLOW FILL TIME: 03:27 FAST FILL TIME: 03:41 REPLENISH TIME: 05:45	LH2 CHILLDOWN TIME: 02:47 SLOW FILL TIME: 02:57	FAST FILL TIME: 03:54 REPLENISH TIME: 05:45	

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				
(EST)	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
445	72.20	54.6	55.30	17	56	II	10.03	61.12	0.0000	-0.2433	II	10.03	55.45	0.0000	-0.2130	II	11.90	56.32	0.0000	-0.2485	II	20.57	61.40	0.0000	-0.4332
500	72.00	54.6	55.11	15	56	II	8.85	60.03	0.0000	-0.2152	II	8.85	54.54	0.0003	-0.1854	II	10.50	54.96	0.0001	-0.2160	II	18.15	60.16	0.0000	-0.3786
515	72.40	55.6	55.99	13	50	II	7.67	59.37	0.0000	-0.1952	II	7.67	54.41	0.0009	-0.1656	II	9.10	54.85	0.0007	-0.1925	II	15.73	59.28	0.0000	-0.3382
530	72.20	55.8	55.90	16	54	II	9.44	60.73	0.0000	-0.2339	II	9.44	55.41	0.0003	-0.2037	II	11.20	55.81	0.0001	-0.2374	II	19.36	60.93	0.0000	-0.4143
545	72.20	55.2	55.60	16	54	II	9.44	60.71	0.0000	-0.2321	II	9.44	55.24	0.0002	-0.2020	II	11.20	55.67	0.0000	-0.2354	II	19.36	60.92	0.0000	-0.4110
600	72.20	55.2	55.60	16	54	II	9.44	60.71	0.0000	-0.2321	II	9.44	55.24	0.0002	-0.2020	II	11.20	55.67	0.0000	-0.2354	II	19.36	60.92	0.0000	-0.4110
615	72.40	54.6	55.50	14	49	II	8.26	59.91	0.0000	-0.2059	II	8.26	54.56	0.0005	-0.1762	II	9.80	54.99	0.0003	-0.2051	II	16.94	59.95	0.0000	-0.3596
630	72.40	55.0	55.70	15	44	II	8.85	60.44	0.0000	-0.2203	II	8.85	55.05	0.0004	-0.1904	II	10.50	55.46	0.0002	-0.2217	II	18.15	60.57	0.0000	-0.3875
645	72.40	55.8	56.09	16	57	II	9.44	60.93	0.0000	-0.2360	II	9.44	55.60	0.0003	-0.2057	II	11.20	56.01	0.0001	-0.2397	II	19.36	61.12	0.0000	-0.4180
700	72.40	54.4	55.39	14	47	II	8.26	59.90	0.0000	-0.2054	II	8.26	54.50	0.0005	-0.1757	II	9.80	54.93	0.0003	-0.2045	II	16.94	59.95	0.0000	-0.3586
715	72.80	55.0	56.04	16	46	II	9.44	61.26	0.0000	-0.2373	II	9.44	55.74	0.0002	-0.2070	II	11.20	56.21	0.0000	-0.2412	II	19.36	61.46	0.0000	-0.4201
730	72.60	54.4	55.59	15	59	II	8.85	60.62	0.0000	-0.2205	II	8.85	55.08	0.0003	-0.1906	II	10.50	55.49	0.0001	-0.2219	II	18.15	60.76	0.0000	-0.3878
745	72.80	54.2	56.00	15	42	II	8.85	60.82	0.0000	-0.2219	II	8.85	55.22	0.0003	-0.1919	II	10.50	55.63	0.0004	-0.2234	II	18.15	60.95	0.0000	-0.3902
800	72.80	55.2	56.18	15	51	II	8.85	60.85	0.0000	-0.2248	II	8.85	55.50	0.0004	-0.1948	II	10.50	55.91	0.0002	-0.2267	II	18.15	60.96	0.0000	-0.3955
815	73.20	55.6	56.77	16	46	II	9.44	61.72	0.0000	-0.2438	II	9.44	56.33	0.0003	-0.2134	II	11.20	56.73	0.0000	-0.2484	II	19.36	61.89	0.0000	-0.4317
830	74.00	53.4	56.43	19	49	II	11.21	63.67	0.0000	-0.2863	II	11.21	58.33	0.0000	-0.2553	II	13.3	59.18	0.0000	-0.2977	II	22.99	64.03	0.0000	-0.5144
845	73.80	55.0	57.05	17	44	II	10.03	62.74	0.0000	-0.2621	II	10.03	57.05	0.0000	-0.2314	II	11.90	57.86	0.0000	-0.2696	II	20.57	62.97	0.0000	-0.4667
900	74.20	53.4	56.63	16	40	II	9.44	62.67	0.0000	-0.2473	II	9.44	56.72	0.0000	-0.2169	II	11.20	57.58	0.0000	-0.2524	II	19.36	62.85	0.0000	-0.4374
915	74.40	54.8	57.53	18	50	II	10.62	63.72	0.0000	-0.2823	II	10.62	58.20	0.0000	-0.2513	II	12.60	59.04	0.0000	-0.2927	II	21.78	64.00	0.0000	-0.5051
930	74.60	54.2	57.42	16	44	II	9.44	63.09	0.0000	-0.2542	II	9.44	57.30	0.0001	-0.2236	II	11.20	57.98	0.0000	-0.2601	II	19.36	63.25	0.0000	-0.4497
945	74.40	52.0	56.09	16	46	II	9.44	62.82	0.0000	-0.2449	II	9.44	56.88	0.0000	-0.2146	II	11.20	57.75	0.0000	-0.2497	II	19.36	63.02	0.0000	-0.4328
1000	74.60	52.4	56.49	19	49	II	11.21	64.23	0.0000	-0.2897	II	11.21	58.88	0.0000	-0.2587	II	13.30	59.76	0.0000	-0.3016	II	22.99	64.60	0.0000	-0.5203
1015	76.00	52.4	57.84	14	44	II	8.26	63.45	0.0000	-0.2339	II	8.26	57.46	0.0002	-0.2035	II	9.80	57.86	0.0000	-0.2361	II	16.94	63.42	0.0000	-0.4077
1030	76.40	52.0	58.02	18	60	II	10.62	65.65	0.0000	-0.2955	II	10.62	60.08	0.0000	-0.2642	II	12.60	60.93	0.0000	-0.3075	II	21.78	65.92	0.0000	-0.5279
1045	75.60	51.0	56.71	18	57	II	10.62	64.82	0.0000	-0.2823	II	10.62	59.27	0.0000	-0.2514	II	12.60	60.14	0.0000	-0.2927	II	21.78	65.13	0.0000	-0.5042
1100	77.00	48.2	56.50	20	55	II	11.80	66.85	0.0000	-0.3161	II	11.80	61.65	0.0000	-0.2847	II	14.00	62.52	0.0000	-0.3317	II	24.20	67.27	0.0000	-0.5688
1115	77.20	50.2	57.82	18	60	II	10.62	66.39	0.0000	-0.2979	II	10.62	60.82	0.0000	-0.2667	II	12.60	61.69	0.0000	-0.3102	II	21.78	66.69	0.0000	-0.5317
1130	77.00	50.8	57.95	19	50	II	11.21	66.59	0.0000	-0.3126	II	11.21	61.19	0.0000	-0.2812	II	13.30	62.05	0.0000	-0.3273	II	22.99	66.92	0.0000	-0.5608
1145	75.80	50.4	56.58	20	55	II	11.80	65.72	0.0000	-0.3104	II	11.80	60.54	0.0000	-0.2791	II	14.00	61.40	0.0000	-0.3253	II	24.20	66.13	0.0000	-0.5592
1200	76.80	51.8	58.30	19	47	II	11.21	66.40	0.0000	-0.3143	II	11.21	61.02	0.0000	-0.2827	II	13.30	61.87	0.0000	-0.3291	II	22.99	66.74	0.0000	-0.5640
1215	75.80	52.2	57.54	17	54	II	10.03	64.65	0.0000	-0.2748	II	10.03	58.90	0.0000	-0.2439	II	11.90	59.76	0.0000	-0.2837	II	20.57	64.89	0.0000	-0.4884
1230	77.40	50.2	58.01	15	50	II	8.85	65.29	0.0000	-0.2556	II	8.85	59.05	0.0000	-0.2249	II	10.50	59.93	0.0000	-0.2610	II	18.15	65.36	0.0000	-0.4482
1245	77.40	49.8	57.79	18	55	II	10.62	66.57	0.0000	-0.2987	II	10.62	61.00	0.0000	-0.2674	II	12.60	61.87	0.0000	-0.3110	II	21.78	66.88	0.0000	-0.5329
1300	77.80	49.2	57.84	15	60	II	8.85	65.65	0.0000	-0.2563	II	8.85	59.42	0.0000	-0.2256	II	10.50	60.31	0.0000	-0.2617	II	18.15	65.73	0.0000	-0.4491
T-0	77.80	49.0	57.73	16	58	II	9.44	66.13	0.0000	-0.2705	II	9.44	60.12	0.0000	-0.2399	II	11.20	61.01	0.0000	-0.2784	II	19.36	66.29	0.0000	-0.4771
AVG.	74.43	53.07	56.66	16.49	NE		9.73	63.03				9.73	57.48				11.54	58.15				19.95	63.24		

(shaded) Period of Ice Team Inspection

Figure 3. "SURFICE" Computer Predictions

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

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

The usual amounts of ice/frost had accumulated on the top, aft, and outboard sides of the LH2 ET/ORB umbilical purge barrier. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on both the aft and forward outboard pyrotechnic canister closeout bondlines indicating thermal shorts. 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 or 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 without contacting Orbiter tiles.

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

Anomaly 001 documented an apparent crack at the upper outboard pyro canister TPS closeout aft bondline on the LH2 ET/ORB umbilical. Although the area was covered by ice and frost, the condition was acceptable per the NSTS-08303 criteria.

Anomaly 002 documented ice/frost formations on the LH2 ET/ORB umbilical aft pyro canister TPS closeout upper bondline. The condition was acceptable per NSTS-08303.

Anomaly 003 documented an 8-inch dogleg crack in the forward surface TPS covering of the -Y vertical strut cable tray at the intersection to the ET/SRB cable tray transition fairing. The 3/8-inch wide crack exhibited no offset and was not filled with ice or frost. The condition was acceptable for launch per NSTS-08303 and CR S041254C.

Anomaly 004 (documentation only) recorded ice/frost formations on the LH2 ET/ORB umbilical pyro canister purge vents, purge barrier (baggie), plate gap purge vents, cable tray vent hole, and LH2 recirculation line bellows. The ice/frost formations were acceptable per NSTS-08303.

Anomaly 005 (documentation only) recorded ice/frost fingers on the LO2 ET/ORB umbilical pyro canister purge vents. The ice and frost formations were acceptable per NSTS-08303.

Anomaly 006 (documentation only) recorded ice/frost formations in the LO2 feedline bellows and support brackets. The ice/frost formations were acceptable per NSTS-08303.

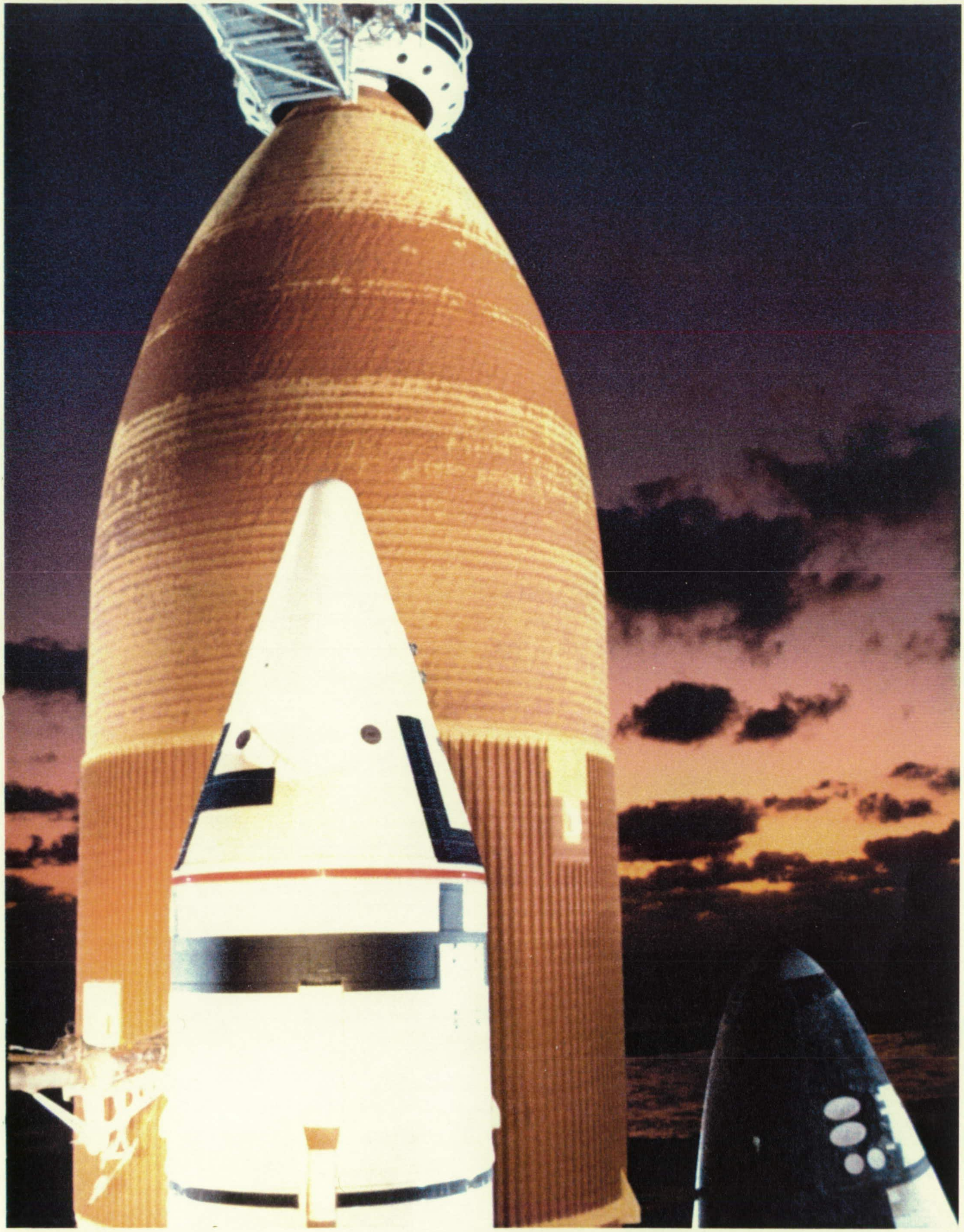
3.5 FACILITY

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.

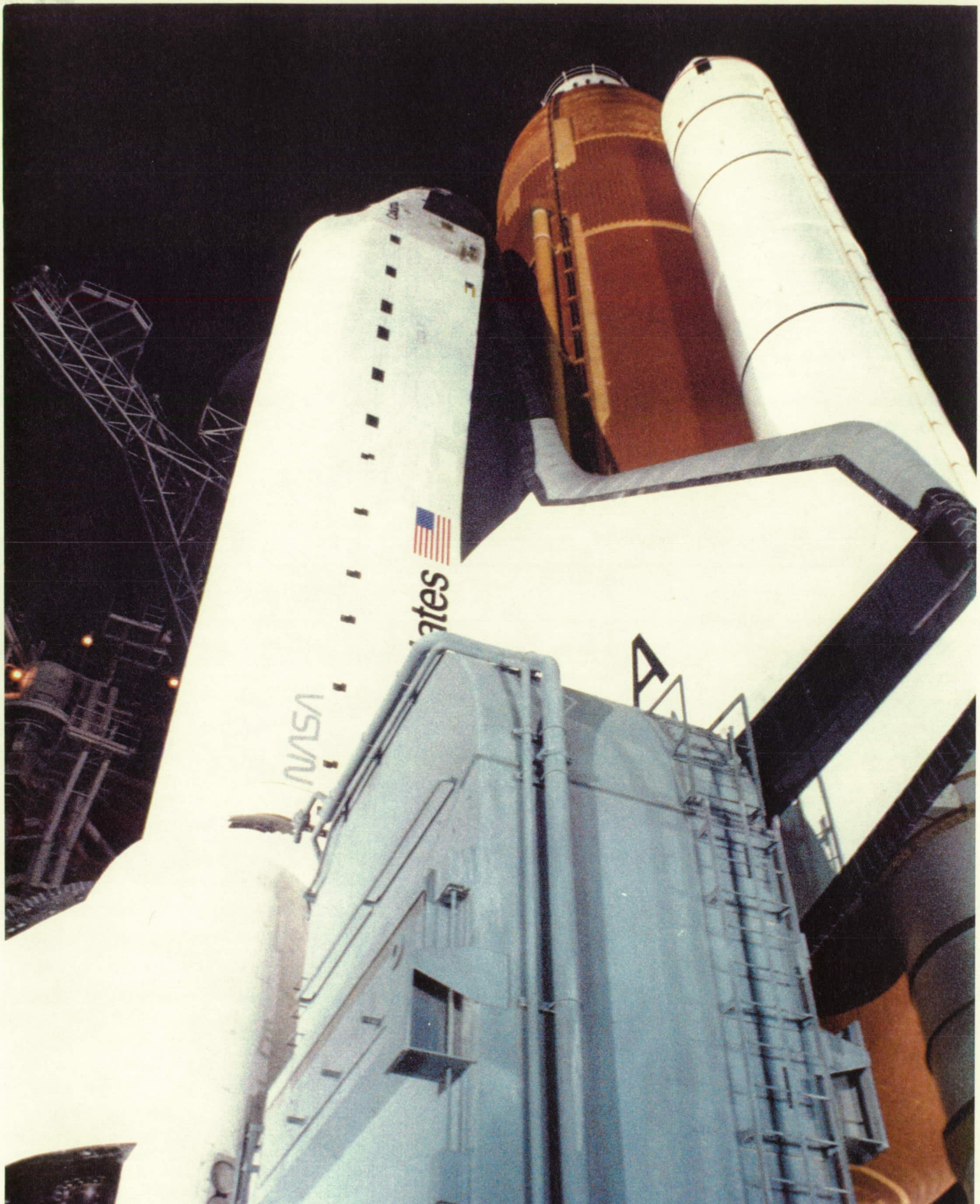
No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals. Typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds.

Leak detectors #23 and #25 located within the GUCP cavity indicated the presence of a hydrogen leak external to the vent line from cryogenic loading slow fill through stable replenish. Readings peaked during vent valve open cycles. The leak reached a maximum value of 44,000 ppm thirty minutes into topping then remained at 20-30,000 ppm during replenish. The suspected area of leakage was at the tank side teflon seal, which mates with the 7-inch GH2 vent quick disconnect probe. More than usual amounts of ice and frost covered the uninsulated areas of the GUCP around the 7-inch line. Post launch inspection and retest of the GSE hardware did not reveal any anomalies.

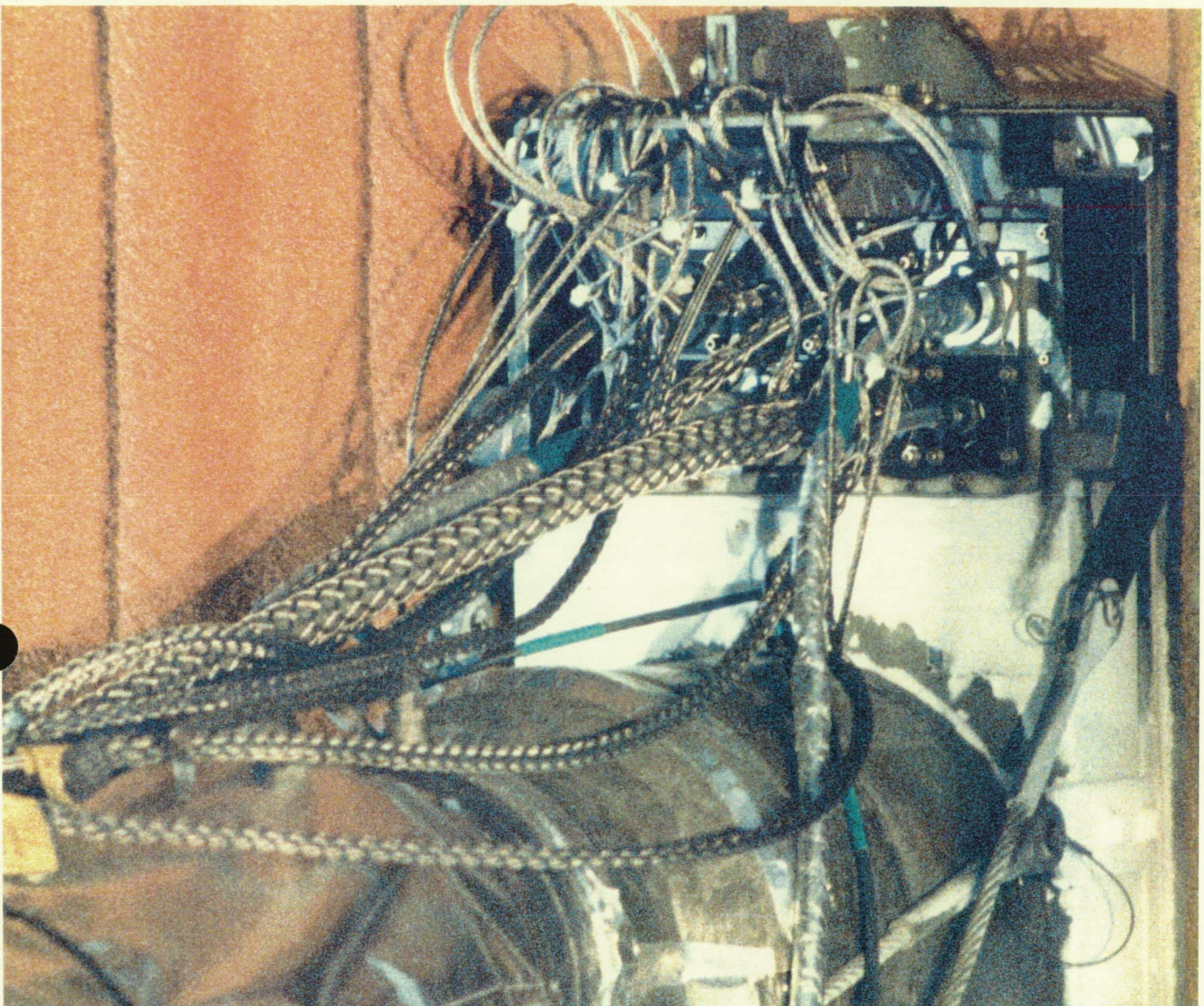
Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. No icicles had formed on the GOX vent ducts.



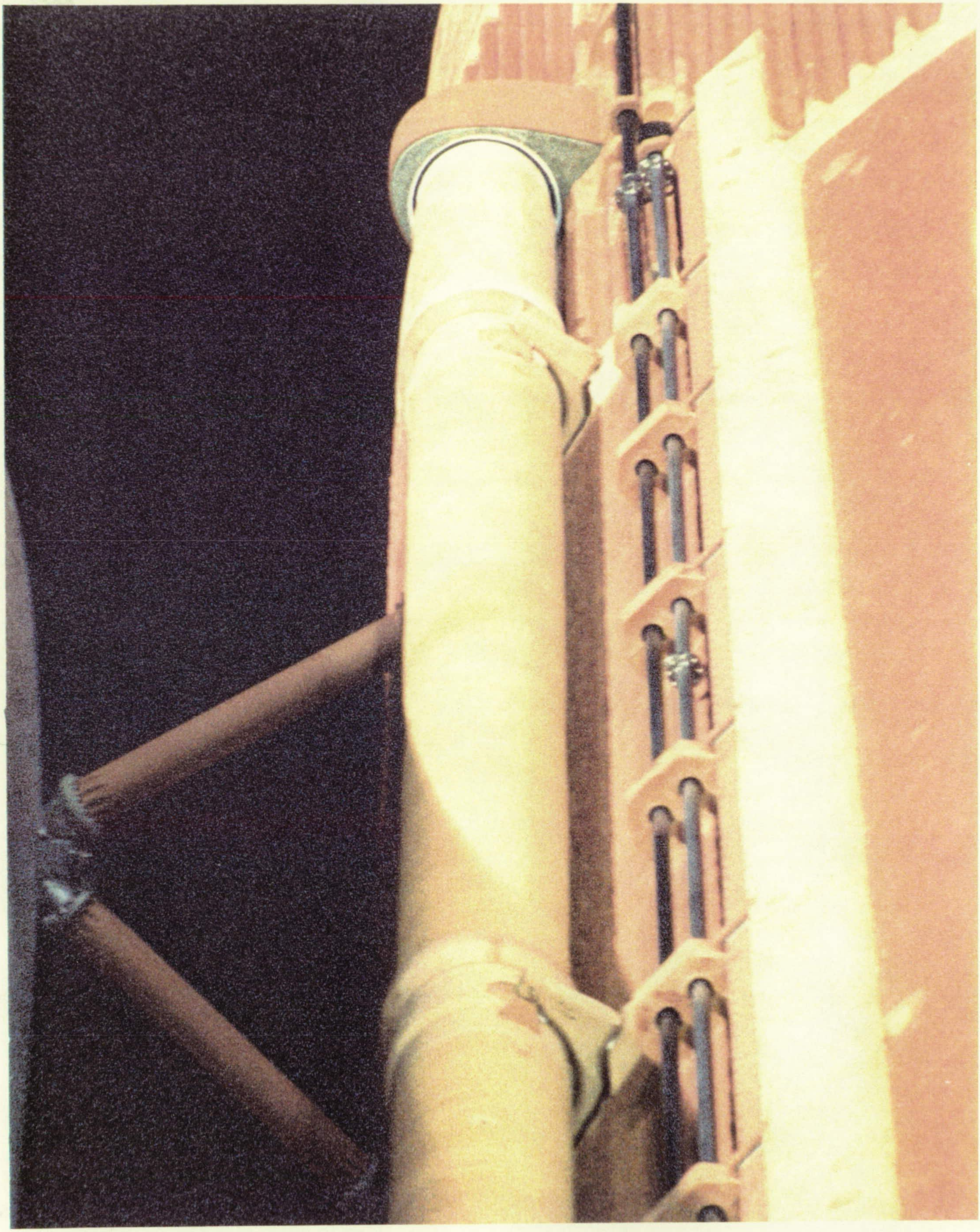
No condensate, ice, or frost accumulation was present on the ET LO2 tank and intertank TPS acreage



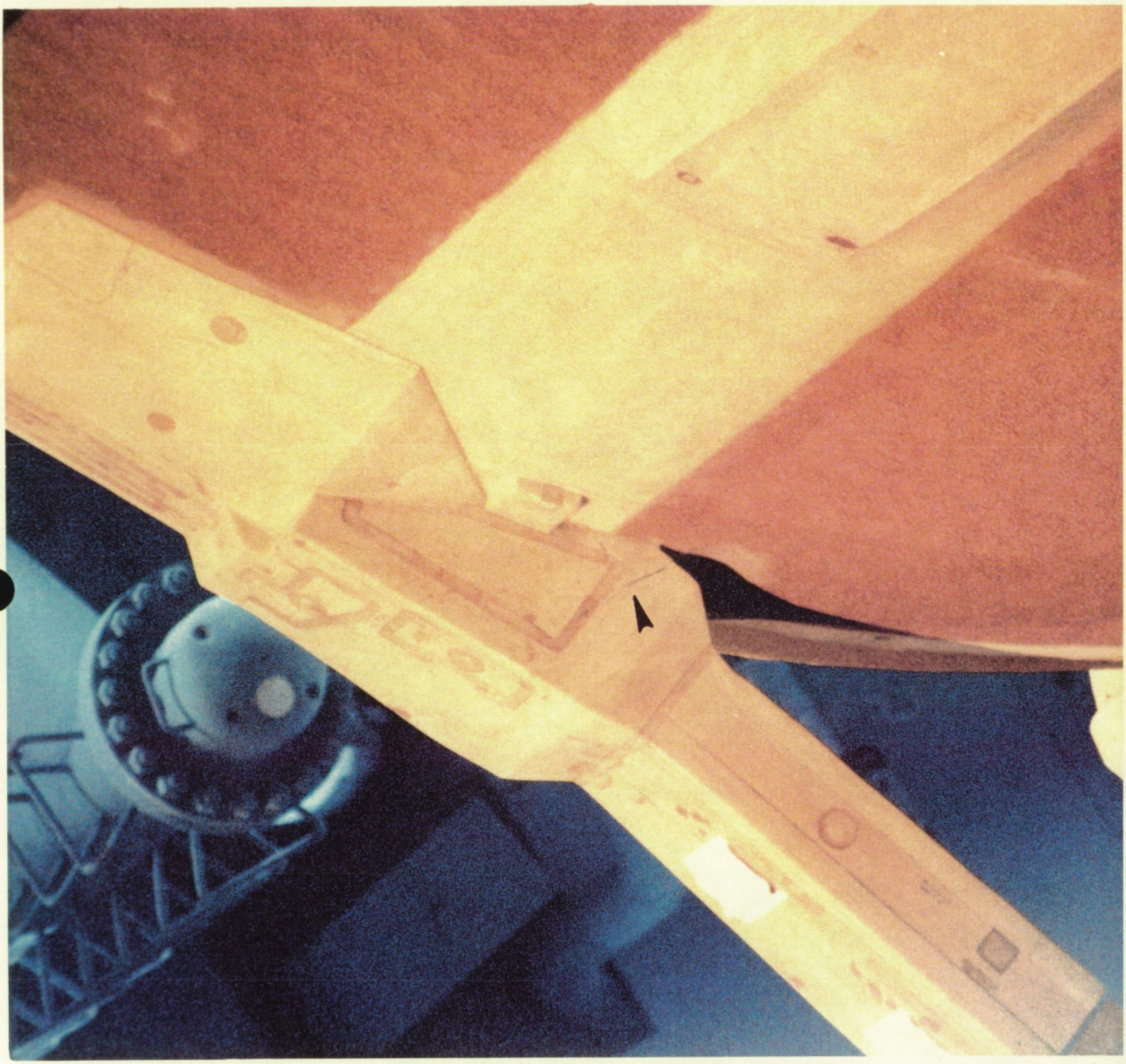
Light condensate, but no ice or frost accumulation, was present on the LH2 tank acreage and aft dome



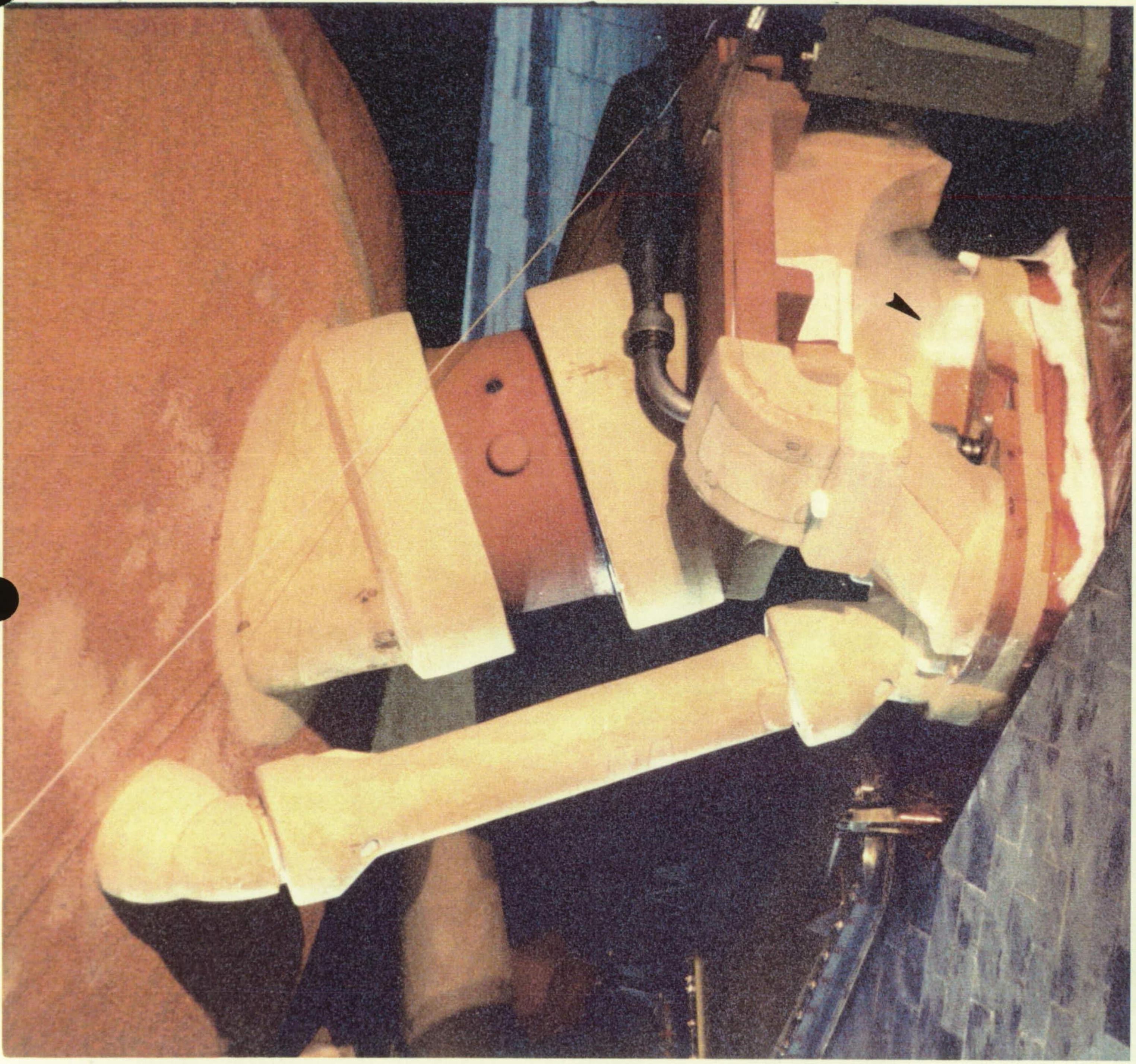
A hydrogen leak external to the vent line occurred from cryogenic loading slow fill through stable replenish. More than usual amounts of ice and frost covered the uninsulated areas of the GUCP around the 7-inch line. Post launch inspection and retest of the GSE hardware did not reveal any anomalies.



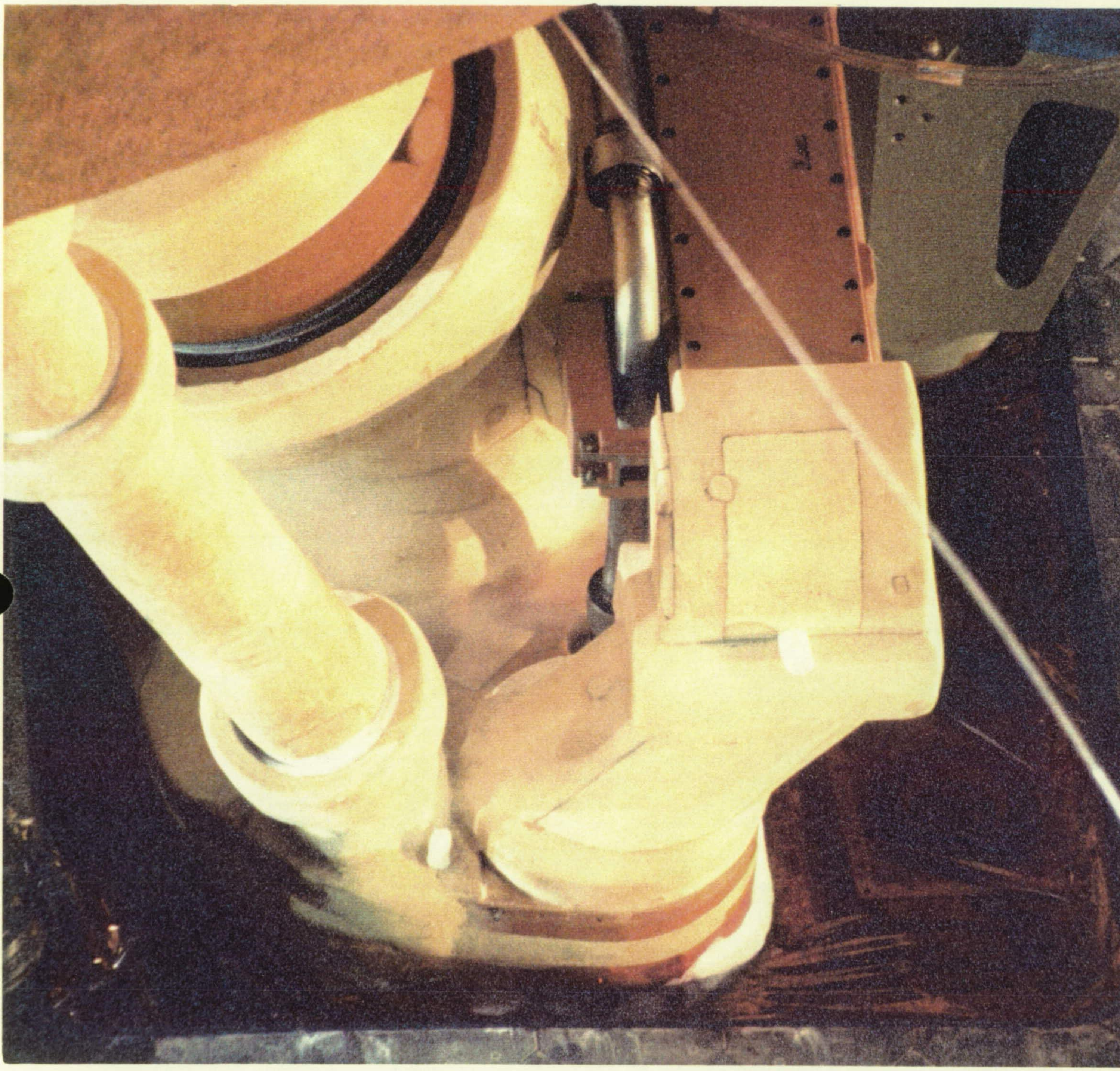
Typical amounts of ice/frost had formed in the LO2 feedline support bracket and upper bellows



An 8-inch long dogleg crack 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



Typical amounts of ice/frost had formed on the top and outboard sides of the LH2 ET/ORB umbilical/purge barrier. Normal amounts of ice had accumulated on the plate gap and pyrotechnic canister purge vents, and the LH2 recirculation line bellows. Ice was present on the forward outboard pyrotechnic canister closeout bondline indicating a thermal short (arrow).



Typical in size, ice/frost fingers had formed on the aft plate gap purge vent and LH2 umbilical cable tray vent hole. The lack of ice or frost on the 17-inch flapper valve actuator access port foam plug closeout indicated a tight seal and nominal closeout.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, pad surface, and pad acreage was conducted on 22 October 1992 from Launch + 2 to 4 hours. No flight hardware or TPS materials were found with the exception of one FRSI plug, which most likely originated from the Orbiter base heat shield.

EPON shim material was intact on all south holddown post shoes but was slightly debonded on HDP #1 and #2. 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 normal plume 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. A preliminary inspection of the GUCP 7-inch line sealing surface was performed in an effort to determine the cause of the hydrogen leak detected during cryogenic loading. No obvious discrepancies were noted. Post launch disassembly and retest of the hardware also revealed no anomalies. A dimensional analysis of the bellows is still in work, but the IPR documenting the condition will most likely be closed as an Unexplained Anomaly (UA). The GH2 vent line exterior surface showed typical signs of SRB plume impingement. The ET intertank access structure also sustained typical plume heating effects.

Damage to the facility appeared to be less than usual. Items found on the pad included:

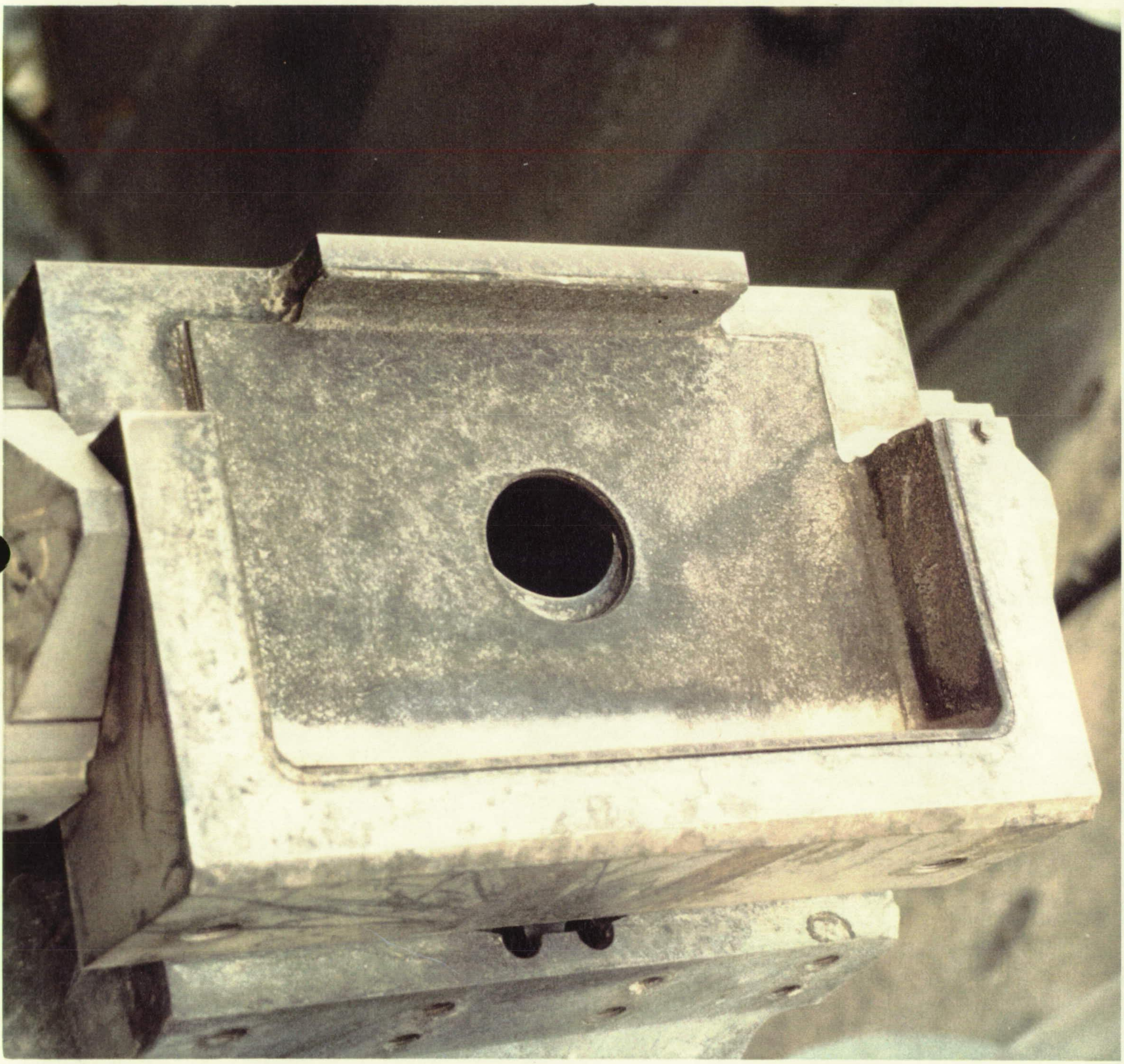
1. A two foot long cable tray rail and a 6-inch long bolt on the FSS 95 foot level near the elevator.
2. A total of three 5-inch diameter rubber disks on the FSS 175 and 215 foot levels.
3. A metal hasp on the FSS 95 foot level deck near slidewire basket #4.
4. A 10-inch long metal tool (chisel) on the FSS 255 foot level near the elevator door.
5. A piece of sheet metal in the SRB flame trench 50 feet north of the MLP.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level. Several of the baskets showed signs of plume impingement effects.
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-3 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 in the LH SRB exhaust hole. 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 74 particles were imaged in the T+138 to 324 second time period. Forty of the particles were imaged by only one radar, 27 particles were imaged by two radars, and 7 particles were imaged by all three radars. The number and signal strength of the detected particles was comparable to the STS-47 mission (73 particles).

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 but slightly debonded from the holddown post shoes.

All of the north holddown post doghouse blast covers were in the closed position and showed typical plume 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 104 film and video data items, which included forty videos, thirty-nine 16mm films, twenty-one 35mm films, and four 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 (RSS STI, C/S-2 STI, OTV 151, 170, 171). The hydrogen burn ignitors functioned normally (OTV 150, 170, 171). One streak was noted in the SSME #1 plume (E-2, 3, 19, 20).

SSME ignition caused numerous pieces of ice/frost to fall from the ET/Orbiter umbilicals. Several of these particles from the outboard side of the LH2 umbilical contacted the aft sill of the umbilical cavity, but did not appear to damage any tiles. There were no unusual vapors or cryogenic drips from the LH2 and LO2 ET/ORB umbilicals during tanking, stable replenish, ignition, or liftoff (OTV 109, 154, 163, 164, C/S-2 STI, E-4, 5, 26).

SSME ignition vibration and acoustics caused the loss of tile surface coating material from four places on the base heat shield outboard of SSME #3 (E-17) and one place between SSME #2 and #3 (E-19).

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

Light frost was present in the -Y ET GOX vent louver at the time of launch. There was no TPS damage to the ET nose cone acreage, footprint, or fairing (OTV 161). The ET "twang" of approximately 31 inches was typical (E-79). The ET nosecone/ pressure spike returned to the 12 inch mark at T-0.

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150, 163). A yellow teflon GSE shim used for repairing the T-0 umbilical peripheral seal fell from the LH2 interface plate/disconnect area at T-0 (E-18).

GUCP disconnect from the External Tank was nominal (OTV 104). There was no external evidence of the hydrogen leak at the 7-inch QD. The GH2 vent line latched with no rebound (OTV 160, E-33). Some slack was present in the static retract lanyard causing it to contact the RH leg of the carrier plate during latchback (E-41, 42, 48, 50).

No ordnance debris fell from the HDP DCS/stud holes. There were no visual indications of stud hang-ups on any holddown posts.

Separation of the SRB T-0 umbilicals from the aft skirts was nominal (EX2, EX3).

Two pieces of thermal curtain tape were loose on the +Y side (90 degree location) of the RH SRB aft skirt (OTV 154) and one piece was loose on the LH SRB aft skirt near HDP #6 (E-31, 34).

SRB north holddown post doghouse blast covers closed normally (E-15, 16). All MLP rainbirds operated properly (E-1, 4, 41, 60, 62).

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, 14, 25, 26).

Numerous particles, most likely small pieces of SRB propellant, fell out of the SRB plume during ascent (E-54, 59, 207, 222).

Clusters of particles falling aft of the Orbiter after completion of the roll maneuver were traced to the forward RCS thrusters and were identified as pieces of RCS paper covers. Other pieces of RCS paper covers were visible passing over the Orbiter wings (E-54, 207, 212, 222).

A particle, first observed behind the left inboard elevon, fell aft and reappeared as two pieces near the SRB BSM cluster at 17:09:53.417 GMT (E-222).

A particle was visible between SSME #2 and #3 at 17:10:01.652 GMT and appeared to be caught in the plume recirculation near the base heat shield. A particle, possibly the same, appeared outboard of SSME #2 at 17:10:01.795 GMT (E-54).

Sunlight reflected off the LH SRB ETA ring (E-207, frame 41-10).

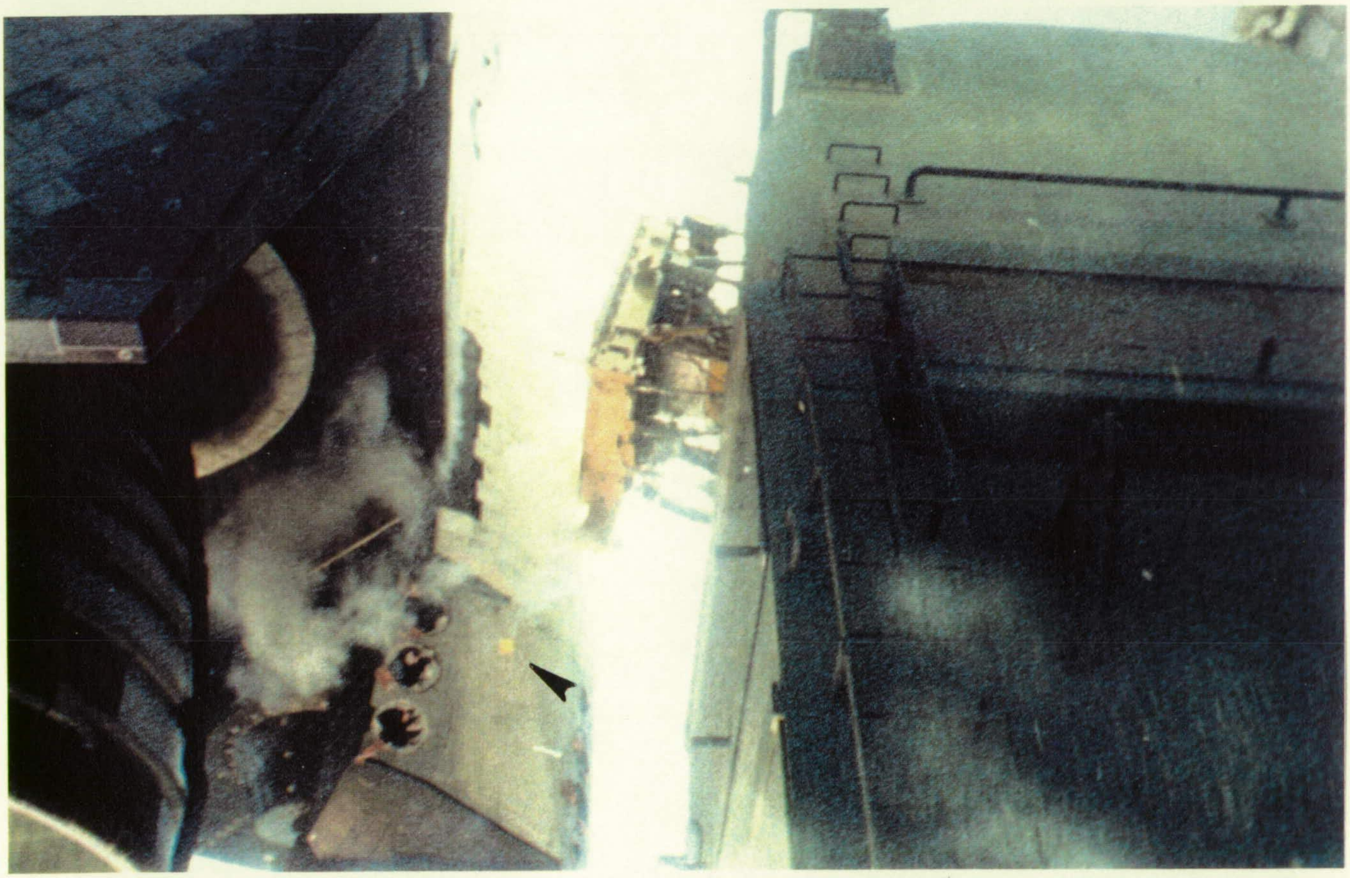
Flashes occurred in the SSME plume during ascent (E-54, 222).

Movement of the body flap was similar to previous flights (E-207, 208, 212, 220).

ET aft dome charring occurred early in ascent (OTV 148, TV 4B). This phenomenon is normal due to the lack of significant condensation on the aft dome at the time of launch.

Exhaust plume recirculation, SRB plume tailoff, SRB separation, and the appearance of SRB slag particles before and after separation were nominal (TV 4B, 5, 13, 21B, E-54, 204, 205, 207, 208, 212, 223).

Frustum separation from the forward skirts and parachute deployment appeared normal. During reefing, one parachute was late in opening but reach full reef before nozzle severance (E-302). Nozzle severance debris was typical. Water splash down was visible in E-302.



A yellow teflon GSE shim used for repairing the T-0 umbilical peripheral seal fell from the LH2 interface plate/disconnect area at T-0.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew and thirty-six 35mm still images were obtained of the ET after separation from the Orbiter. OV-102 was equipped to carry umbilical cameras: one 35mm (60 still frames), one 16mm motion picture camera with 10mm lens, and one 16mm motion picture camera with a 5mm lens.

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

A piece of dark material that appeared from an area behind the LH2 ET/ORB umbilical cable tray, fell aft, and broke into numerous smaller pieces appeared to be a thin layer of fire barrier material from the umbilical.

SRB separation from the ET was nominal. Separation of the -Y ET/SRB upper and diagonal struts appeared normal. No loss of K5NA from the upper strut fairing was visible. No anomalies were observed on the LH SRB segment cases and joints, forward skirt, and frustum.

Separation of the ET/ORB umbilicals appeared normal. Numerous pieces of ice, frozen hydrogen, and small chunks of TPS drifted past the umbilical cameras. A small piece of foam with fire barrier material attached floated by the camera. It most likely originated from the outboard side of the LH2 umbilical near the pyro canister closeout. A white cylindrical rough-edged object also drifted through the field of view and was most likely an ice finger from a forward purge vent tube inside the umbilical. Although not considered an anomaly, this type of ice formation had not been observed in umbilical separation films before.

ET structural 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, and aft dome acreage. Plume recirculation and aft dome heating caused the usual charring and "popcorning" of the NCFI foam.

Erosion/ablation/charring of TPS on the aft surfaces of the ET/ORB umbilical cable trays and the vertical strut/cable trays was typical.

Frozen hydrogen adhered to the LH2 ET/ORB umbilical interface. Small pieces of foam were missing from the vertical and horizontal sections of the umbilical cable tray, the umbilical support strut TPS covering, and the forward outboard pyro canister closeout. A section of the red RTV seal was missing from the aft inboard corner of the LH2 umbilical. This section of material adhered to the Orbiter side of the umbilical interface and was still attached after Orbiter landing.

Pieces of TPS were missing from the LO2 ET/ORB umbilical cable tray vertical and horizontal sections. Possible TPS damage had occurred at the forward inboard corner of the LO2 umbilical.

Erosion and "popcorning" on the LO2 feedline flange closeouts and the +Y thrust strut flange closeout was typical.

A light colored area that may be a possible divot was visible on the ice/frost ramp at XT-2028.

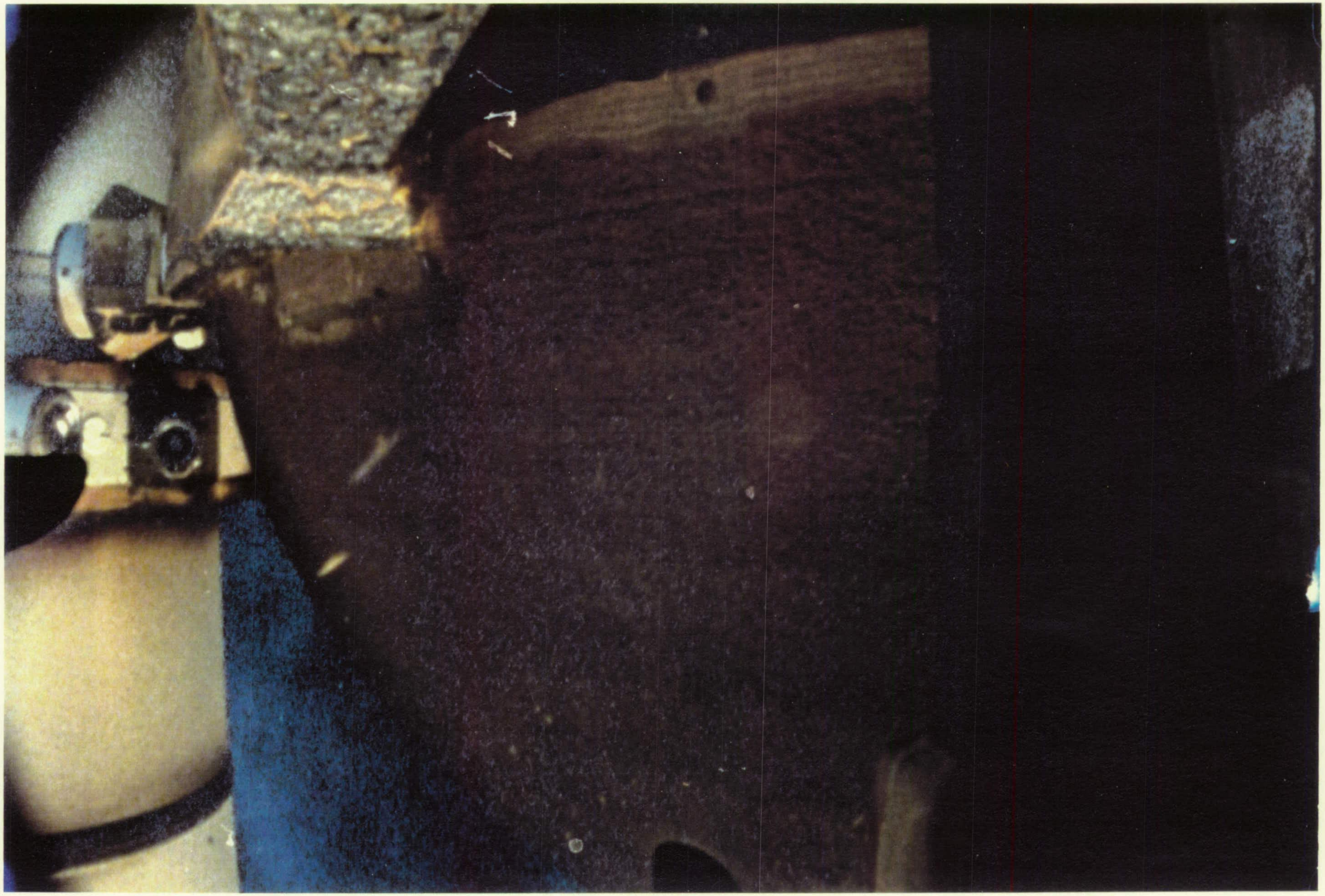
A 5-inch divot to substrate was present in the LH2 tank acreage at XT-1399 adjacent to a previously sanded area.

Some of the left bipod jack pad TPS closeout was missing. Foam was also missing from the aft outboard corner of the LH bipod ramp closeout.

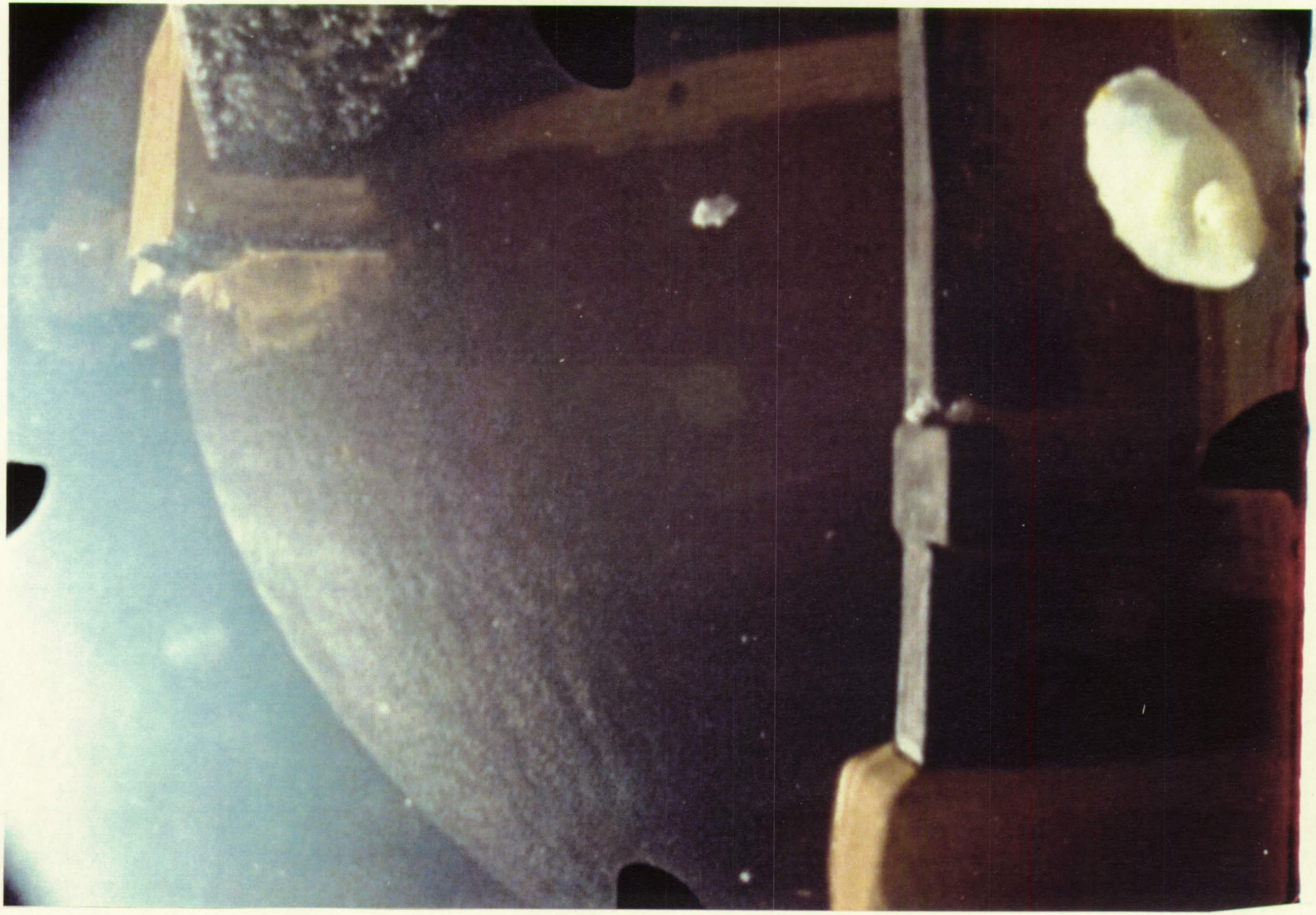
A possible divot may have occurred in the LH2 tank-to-intertank flange closeout just aft of the LH bipod spindle. Otherwise, there were no divots in the flange closeout -Y+Z and +Y+Z quadrants where divots have typically occurred on previous tanks.

At least 20 small pieces of TPS were missing from intertank stringers forward of the LH2 tank-to-intertank flange/bipod area. No metal substrate/primer was visible.

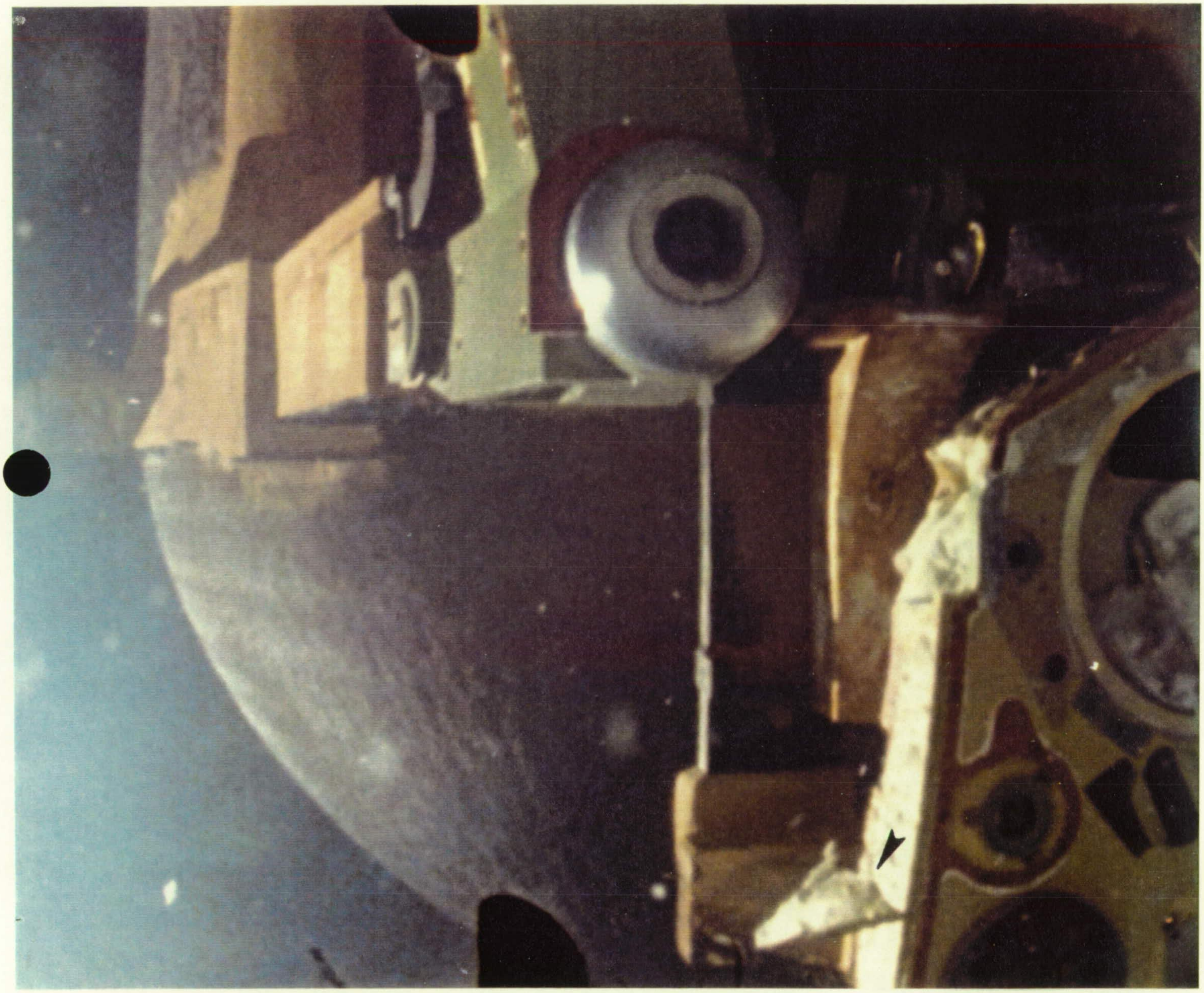
A small piece of debris inside the aft compartment drifted into the field of view between the camera lens and the umbilical view port.



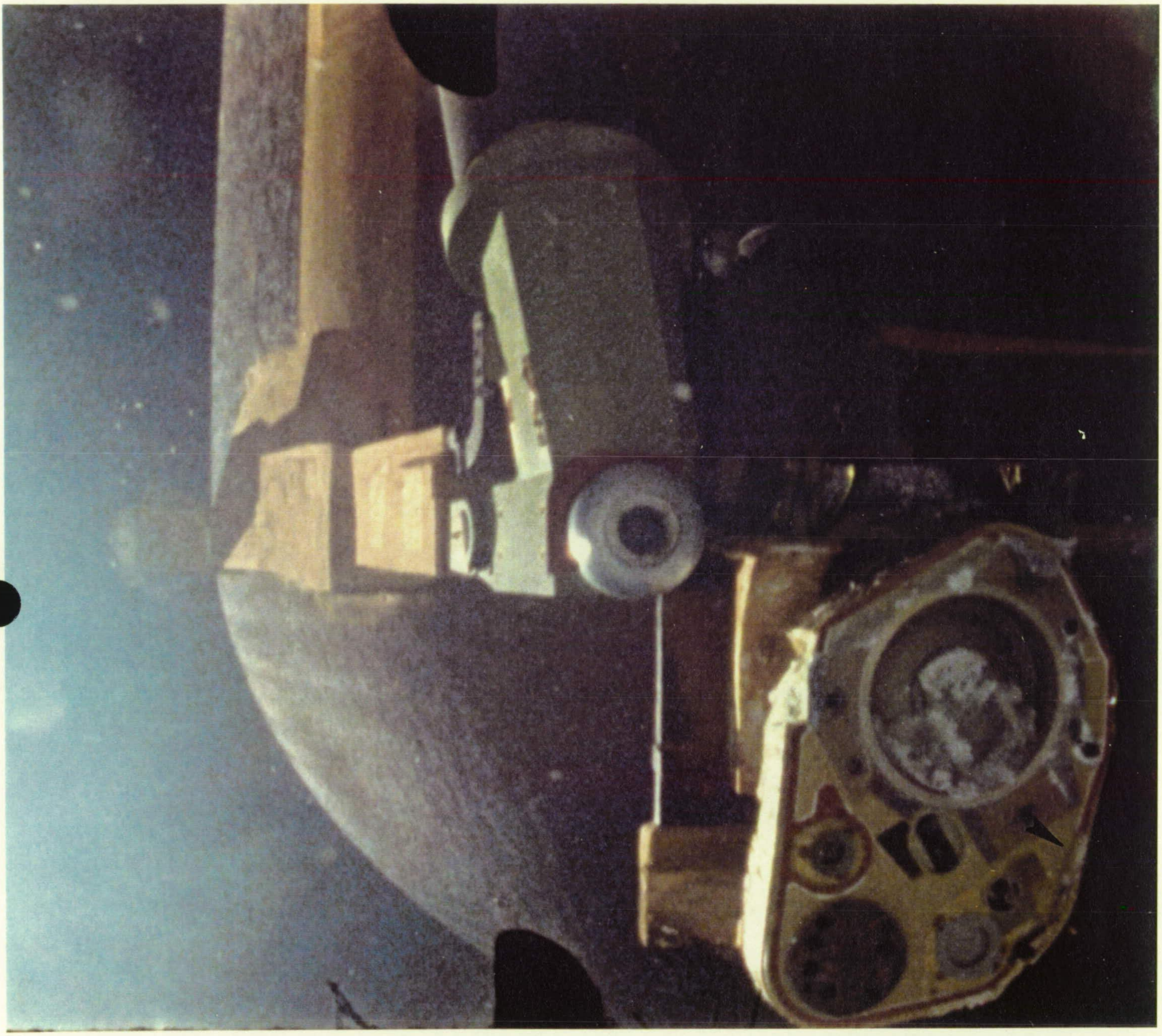
Wide angle view from a camera in the LH2 ET/ORB umbilical showed nominal separation of the LH SRB from the External Tank. Note erosion/loss of material from the TPS on the vertical strut/cable tray aft surface and the upper strut fairing.



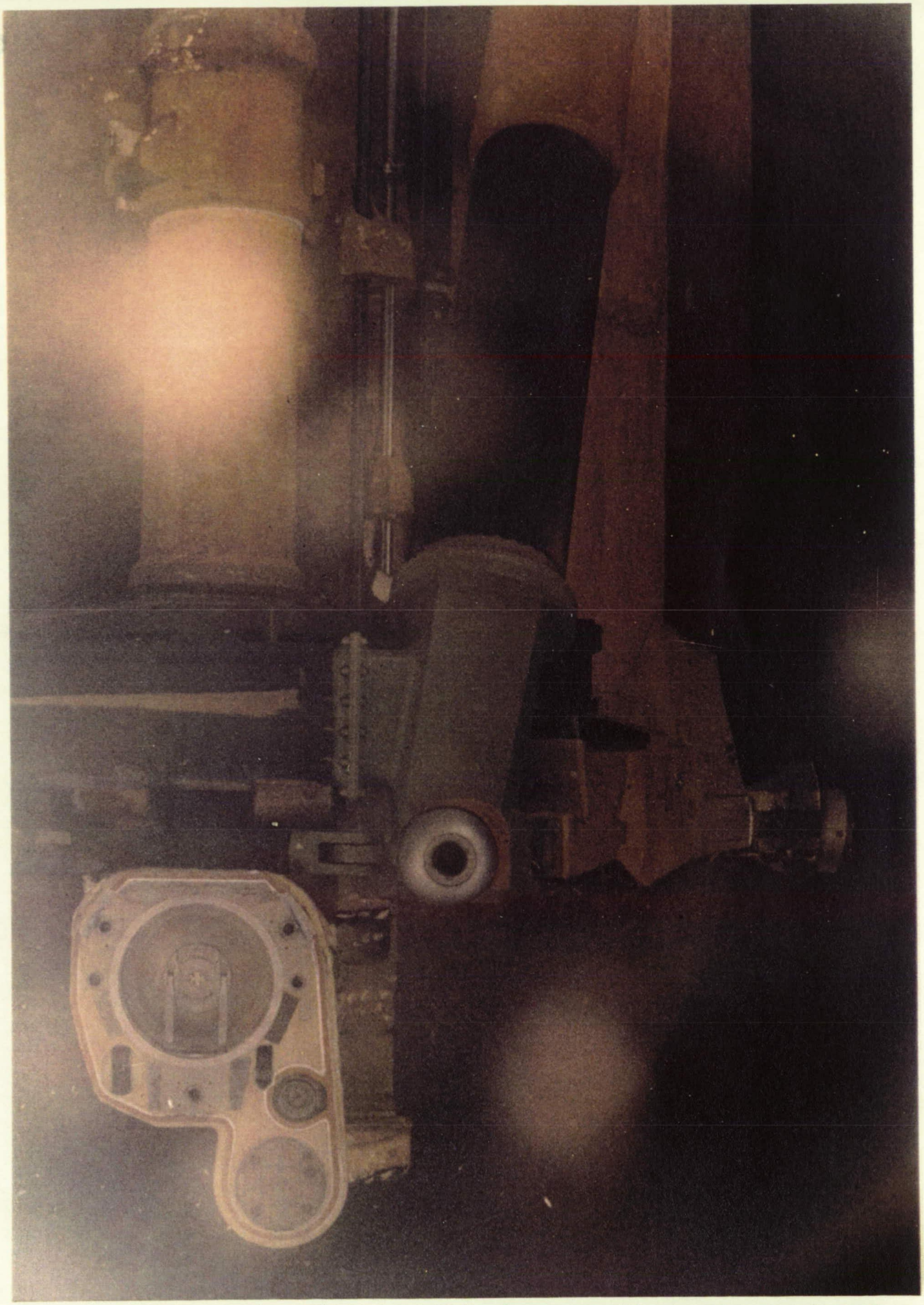
A white cylindrical rough-edged object drifted through the field of view and was most likely an ice finger from a forward purge vent tube inside the umbilical. Although not considered an anomaly, this type of ice formation had not been observed in umbilical separation films before.



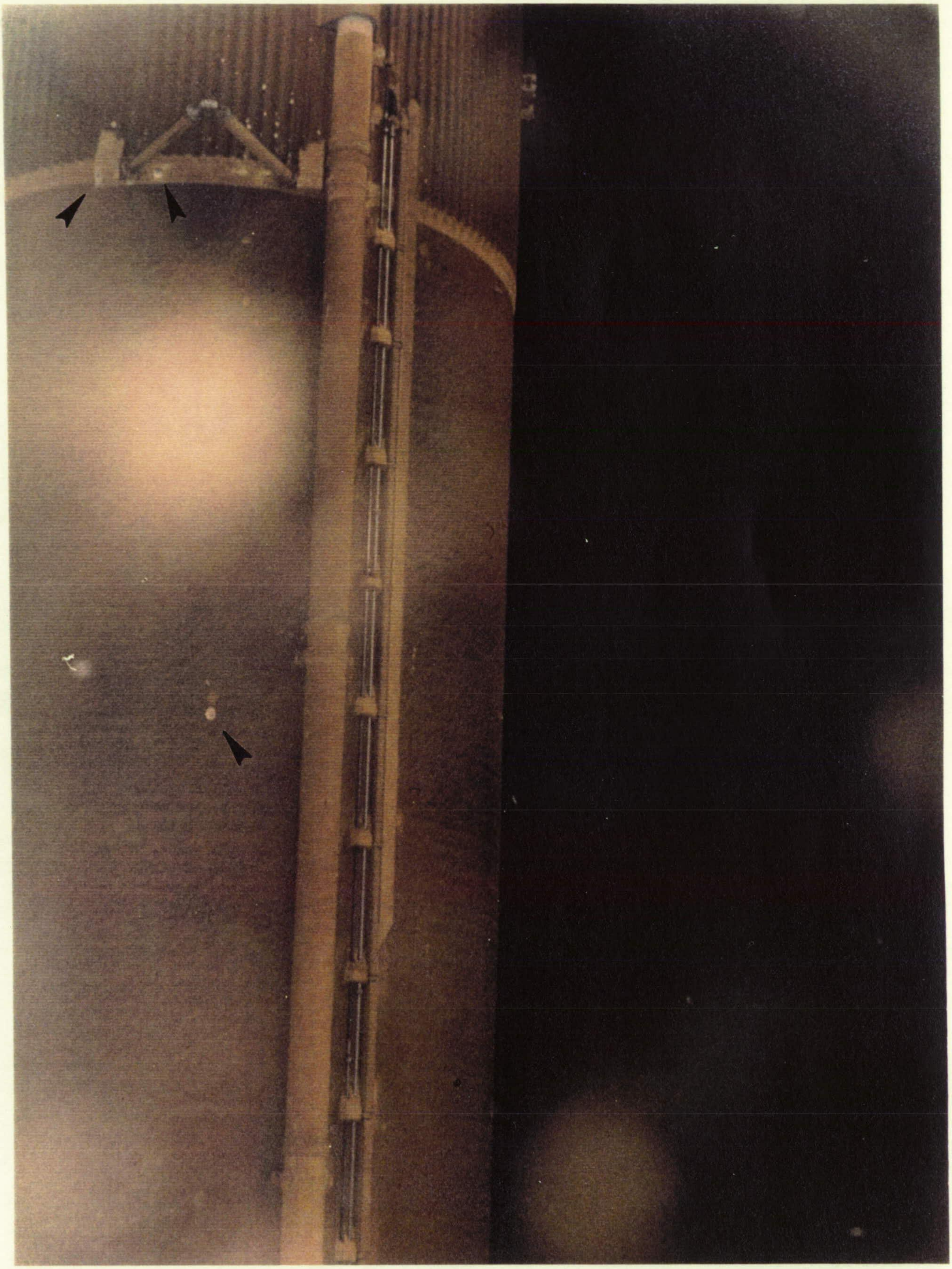
A small piece of foam with fire barrier material attached floated by the camera (arrow). It appeared to originate from the upper outboard side of the LH2 umbilical at the pyrotechnic canister closeout.



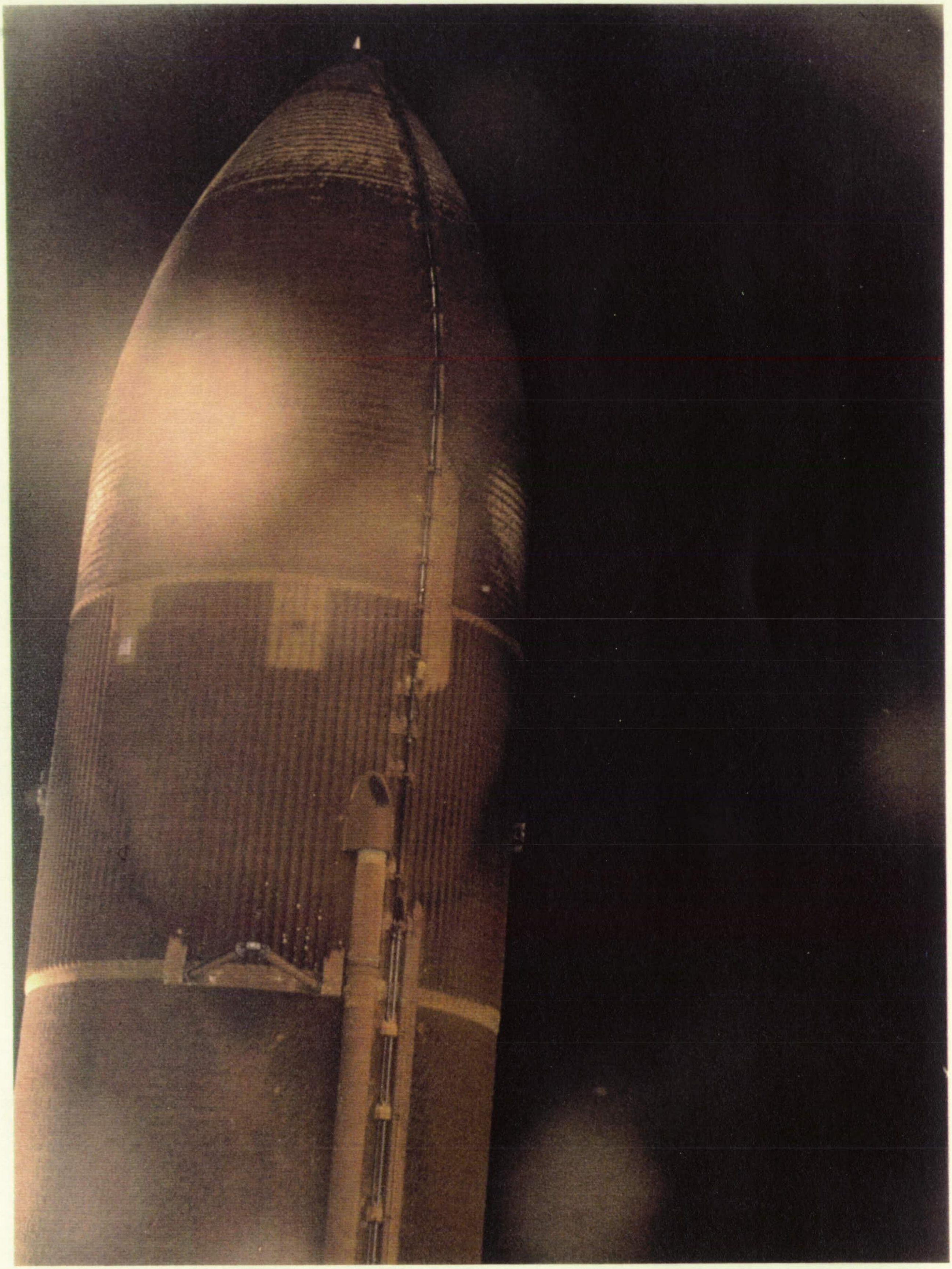
Structural separation of the LH2 ET/ORB umbilical appeared normal. Some TPS was lost from the upper outboard pyro canister closeout at separation. Rough appearance of the umbilical top and outboard sides was caused by blistering of the fire barrier material. A section of the red purge seal was missing from the aft inboard corner of the LH2 umbilical. This section of material adhered to the Orbiter side of the umbilical interface and was still attached after Orbiter landing.



View from the LO2 ET/ORB umbilical separation camera showed possible TPS damage at the forward inboard corner of the LO2 umbilical. Pieces of TPS were missing from the vertical and horizontal sections of the umbilical cable tray.



A 5-inch divot to substrate was present in the LH2 tank acreage at XT-1399 adjacent to a previously sanded area. Some of the left bipod jack pad closeout was missing. Foam was also missing from the aft outboard corner of the LH bipod ramp closeout.



At least 20 small pieces of TPS were missing from intertank stringers forward of the LH2 tank-to-intertank flange/bipod area. No metal substrate or primer was visible. There were no divots in the flange closeout -Y+Z and +Y+Z quadrants. Post flight (ascent) condition of the LO2 tank/nosecone was nominal.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 26 film and video data items, which included eleven videos, nine 16mm high speed films, and six 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 just after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal. A slight crosswind blew the drag chute somewhat westward relative to the Orbiter and caused the nose to yaw eastward. Use of nosewheel steering and braking brought 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 26 October 1992 from 0800 to 1100 hours. From a debris standpoint, both SRB's were in good condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had 18 MSA-2 debonds over fasteners and one 1.5" diameter area of missing TPS in the -Y+Z quadrant at the 336 ring frame. Minor localized blistering of the Hypalon paint had occurred predominantly along the 395 ring (Figure 4). 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.

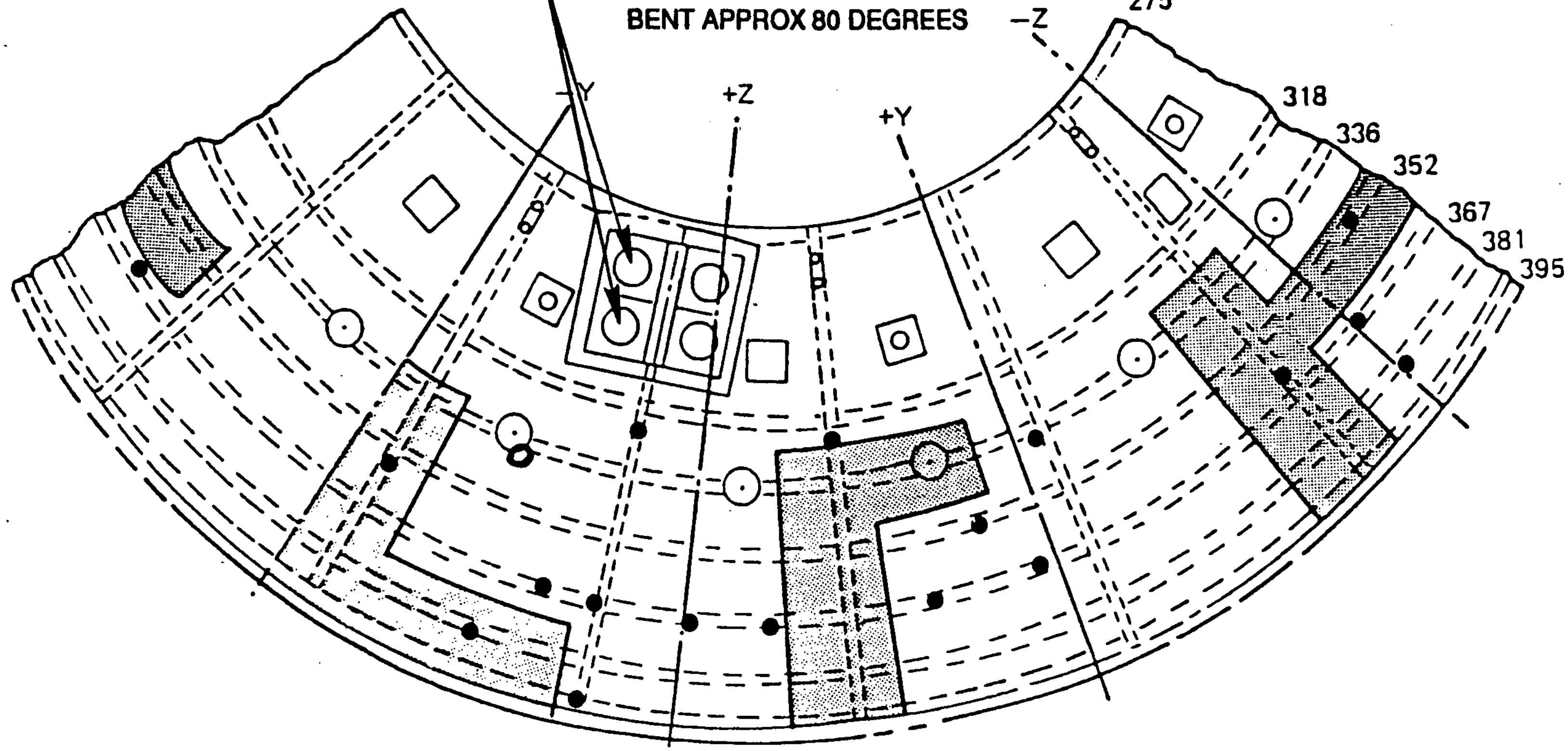
The RH forward skirt exhibited no missing TPS, but did have two debonds. The first debond was located at approximately 240 degrees, station 480, and measured 3.5" x 3" in size. The second debond was located at approximately 150 degrees, station 470, and measured 2.5" x 1.5" in size. Both RSS antennae covers/phenolic base plates were intact and undamaged. Minor blistering of the Hypalon paint occurred on the 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. Two fasteners on the IEA cover were sheared by water impact. Two foam cavities, 1.6 x 0.5 x 1.3 inches and 1.3 x 0.4 x 0.7 inches, were present in the forward-facing ETA ring TPS. One cavity was located near the systems tunnel side of the IEA; the second was located near the upper strut. The adjacent foam in these cavities will be analyzed in an attempt to determine if a debris impact was the cause. The upper strut fairing (milk can) was missing a 7" x 3" section of K5NA and the substrate was charred.

All three aft booster stiffener rings sustained water impact damage. A 5" x 6" area of K5NA was missing from the center aft booster stiffener ring splice plate closeout. Though the remaining material showed signs of delamination, the surfaces were not sooted indicating the material was most likely lost at water impact.

Figure 4. **RIGHT SRB FRUSTUM**



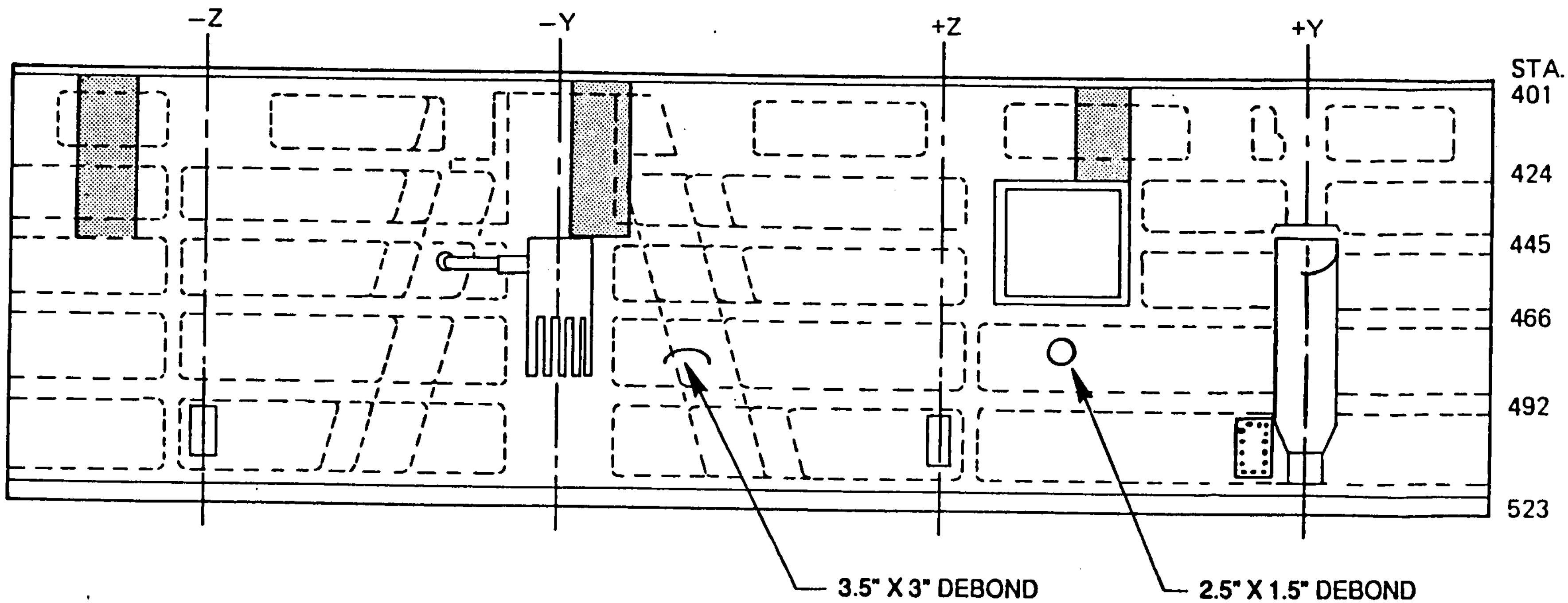
MISSING TPS

O 1

DEBONDS

● 18

Figure 5. **RIGHT SRB FWD SKIRT**



TPS MISSING

NONE

DEBONDS

2

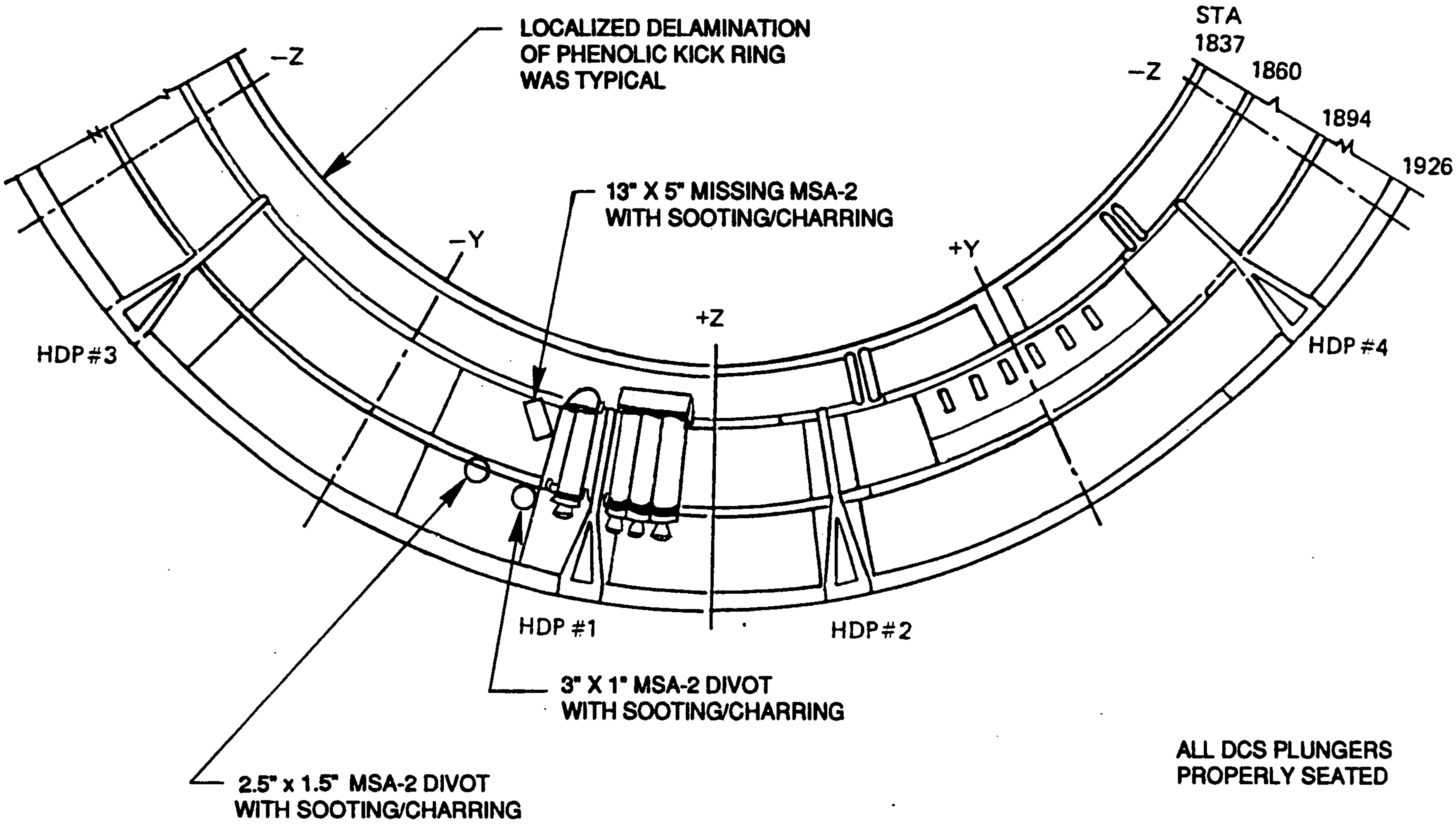
MINOR BLISTERING OF HYPALON PAINT AT ET/SRB FORWARD ATTACH POINT

EGG/V 326A

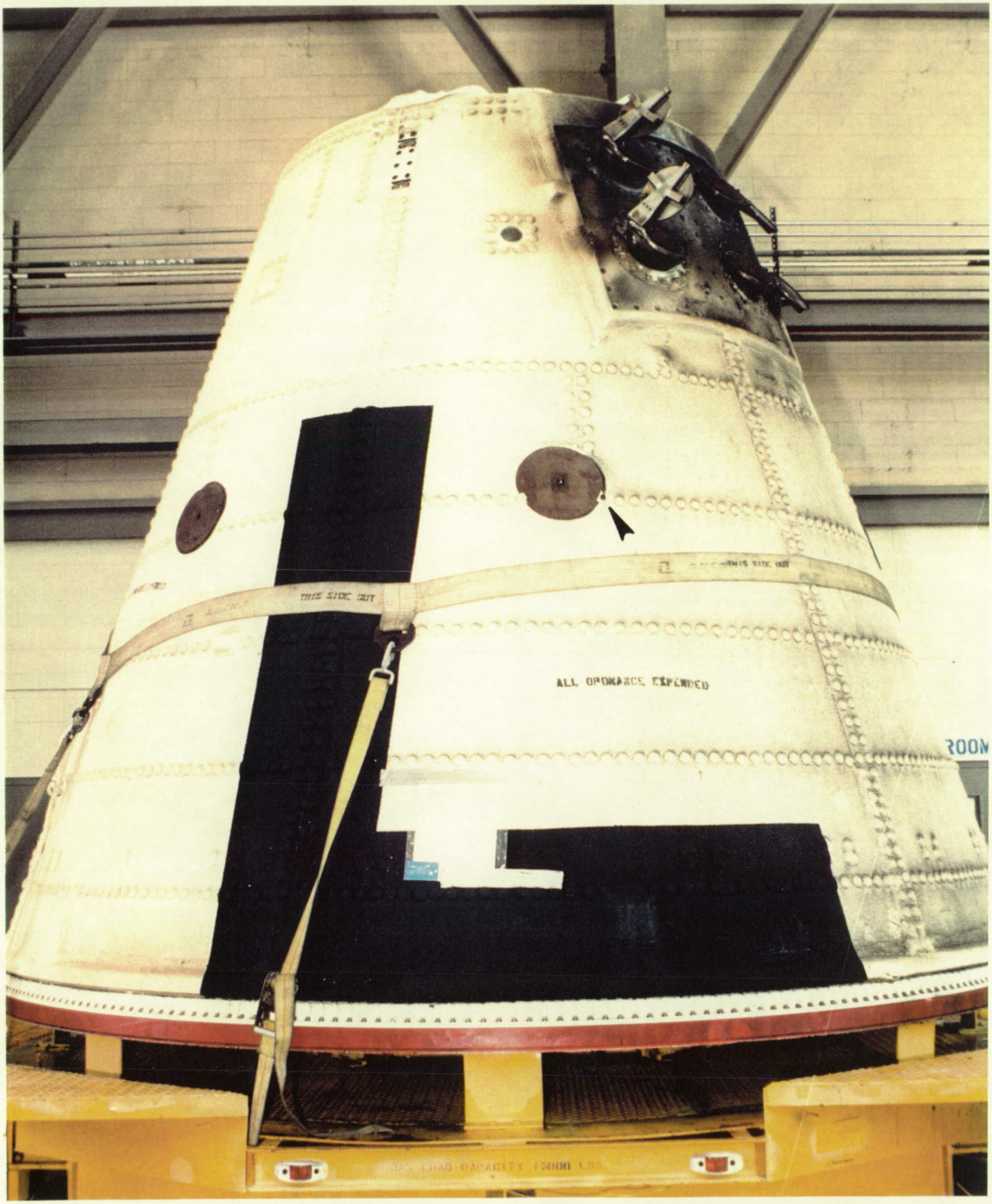
The phenolic material on the kick ring was delaminated. Two divots, measuring 13" x 5" and 3" x 1", had occurred on the aft skirt acreage TPS just to the -Y side of the single BSM. Some of the material along the aft edge of the divots appeared sooted/charred. A third divot, measuring 2.5" x 1.5", had occurred between the single BSM and the -Y axis at station XB-1894 partially exposing two fastener head covers (Figure 6). Samples were taken from all three locations for laboratory analysis. K5NA was missing from all BSM nozzles.

Approximately 50 percent of the EPON shim was missing from HDP #3 aft skirt foot. The substrate was sooted/charred indicating that the shim material was lost prior to water impact. All Debris Containment System (DCS) plungers were seated properly. This was the eleventh flight utilizing the optimized link.

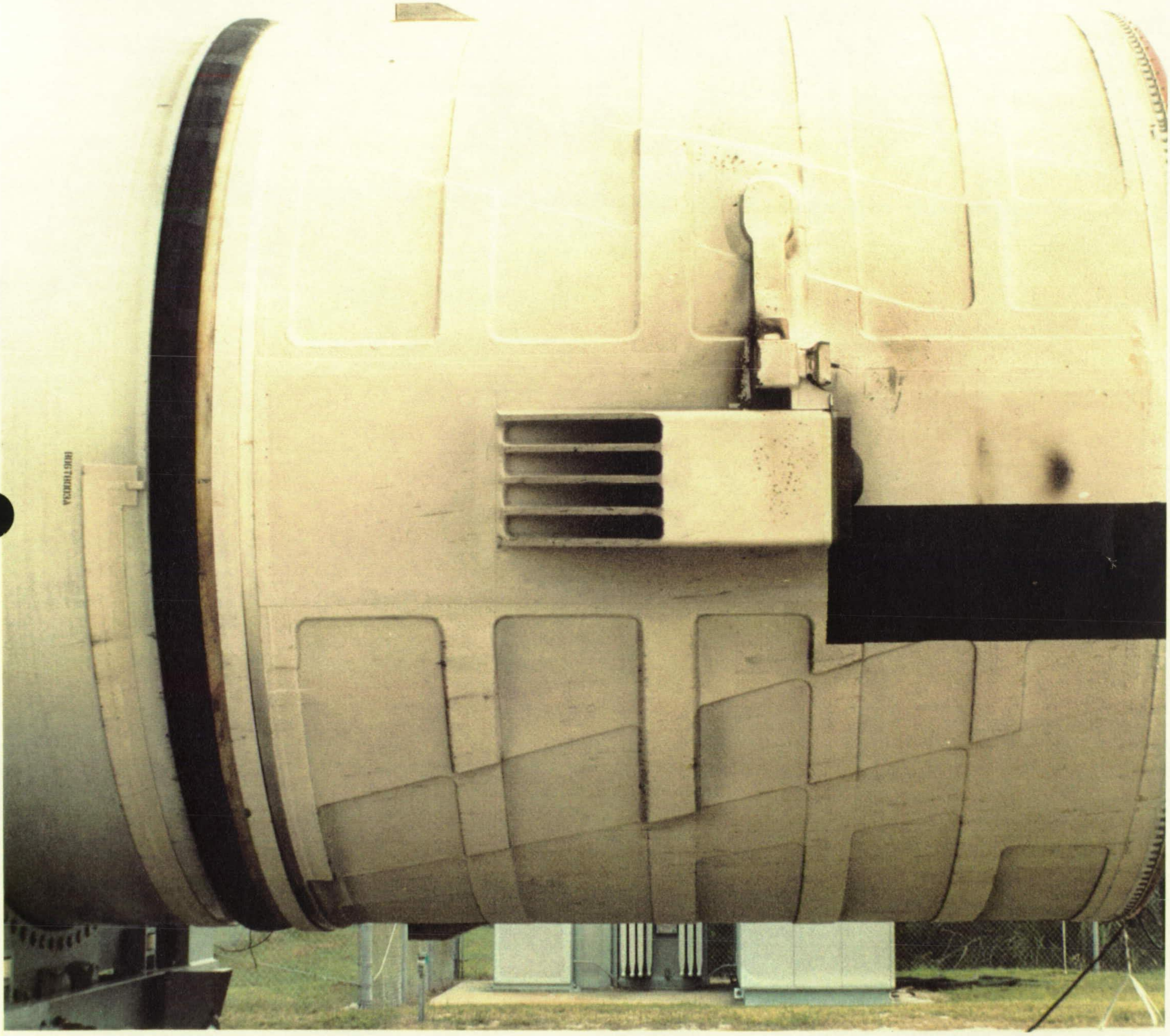
Figure 6. **RIGHT SRB AFT SKIRT EXTERIOR TPS**



326C

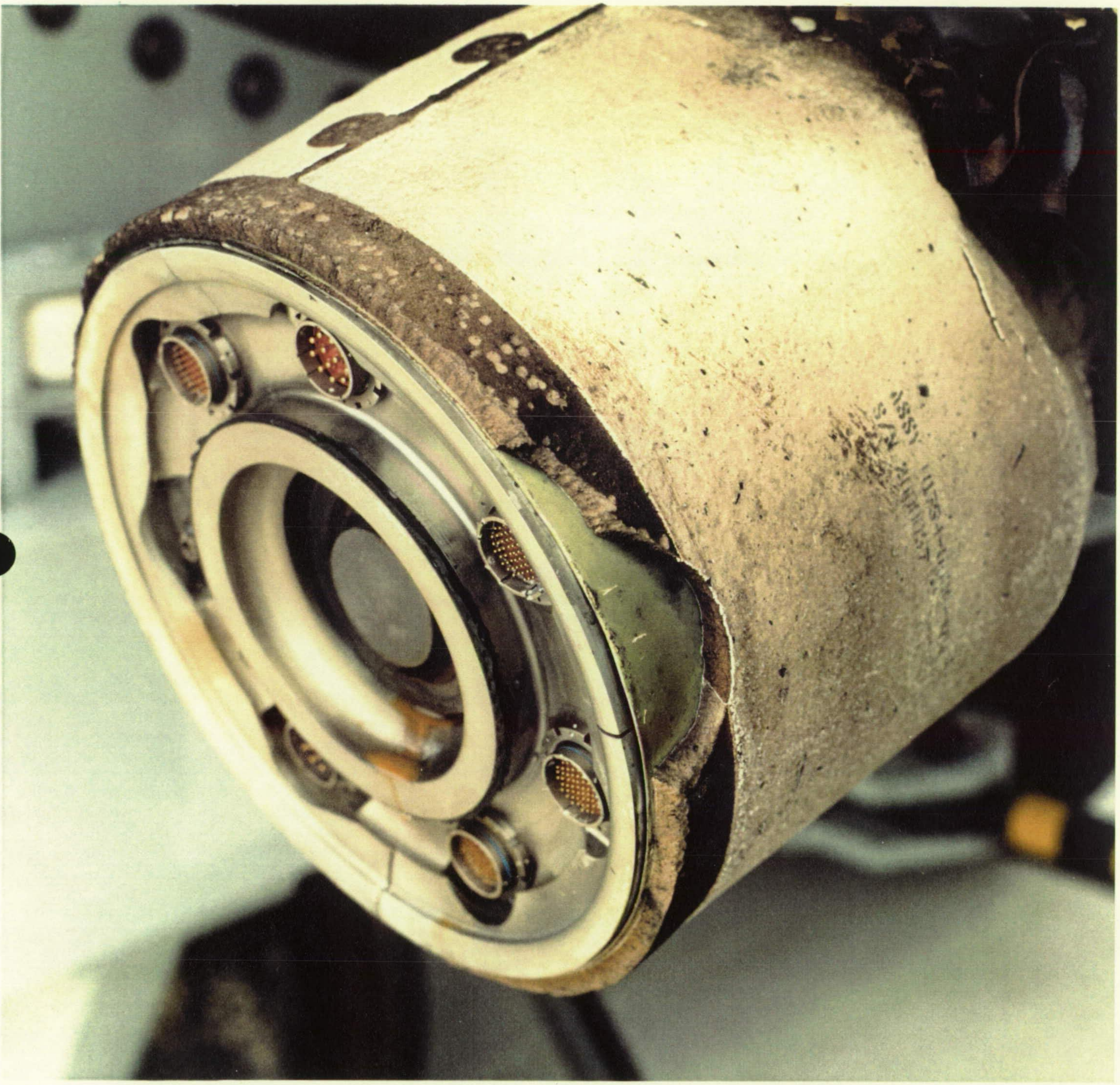


The RH frustum had 18 MSA-2 debonds over fasteners and one area of missing TPS near the pressure port (arrow). All BSM aero heat shield covers were locked in the fully opened position though the left two cover attach rings had been bent by parachute riser entanglement.

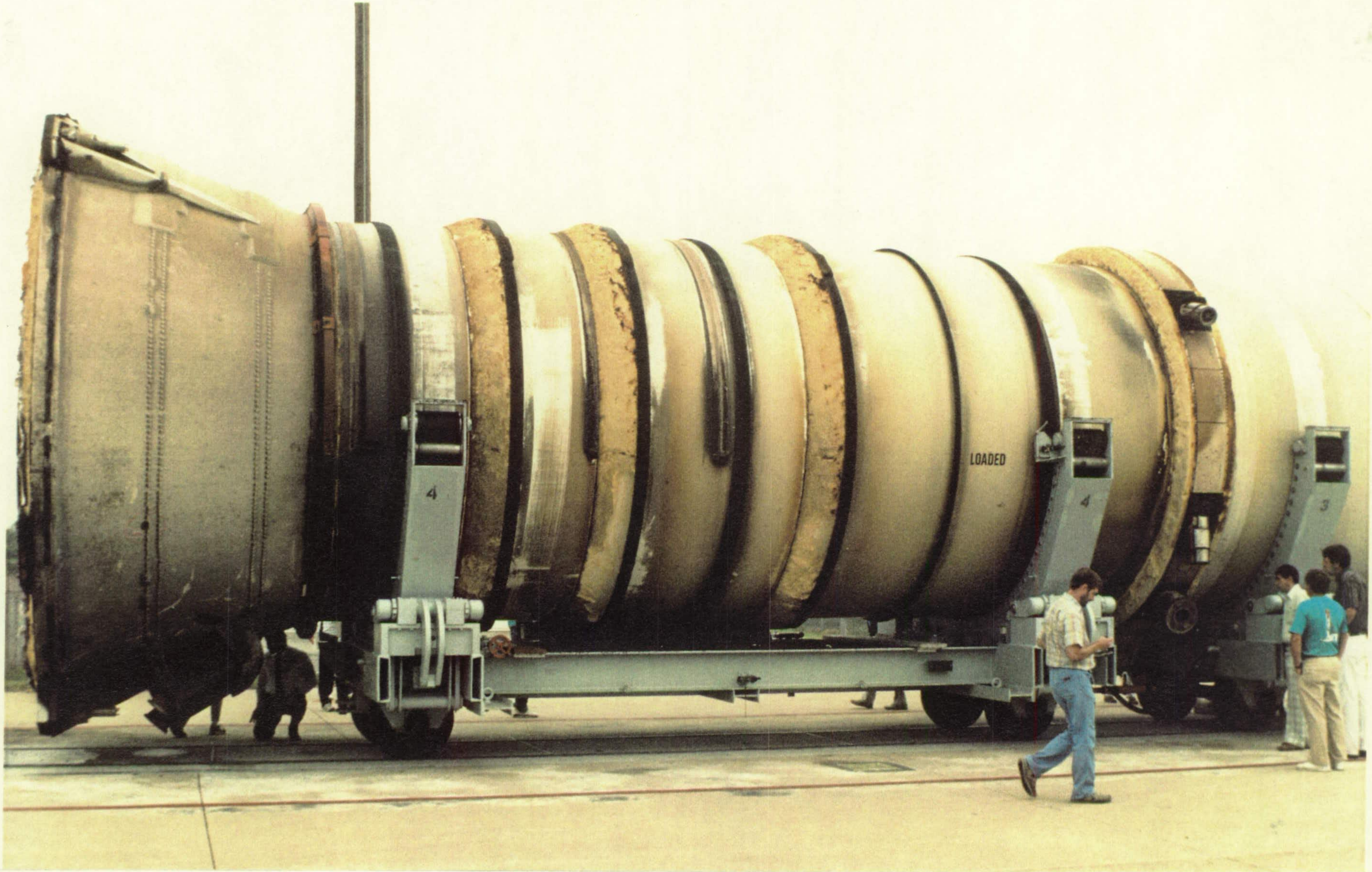


The RH forward skirt was missing no TPS, but did have two MSA-2 debonds. Minor blistering of the Hypalon paint occurred on the forward ET/SRB attach point. Both RSS antenna covers/TPS were intact and undamaged.

Two cavities were present in the forward-facing ETA ring TPS. Post flight analysis revealed no evidence of embedded debris or foreign material. The cavities had experienced a full ascent heat load and were most likely present prior to launch rather than an in-flight occurrence.

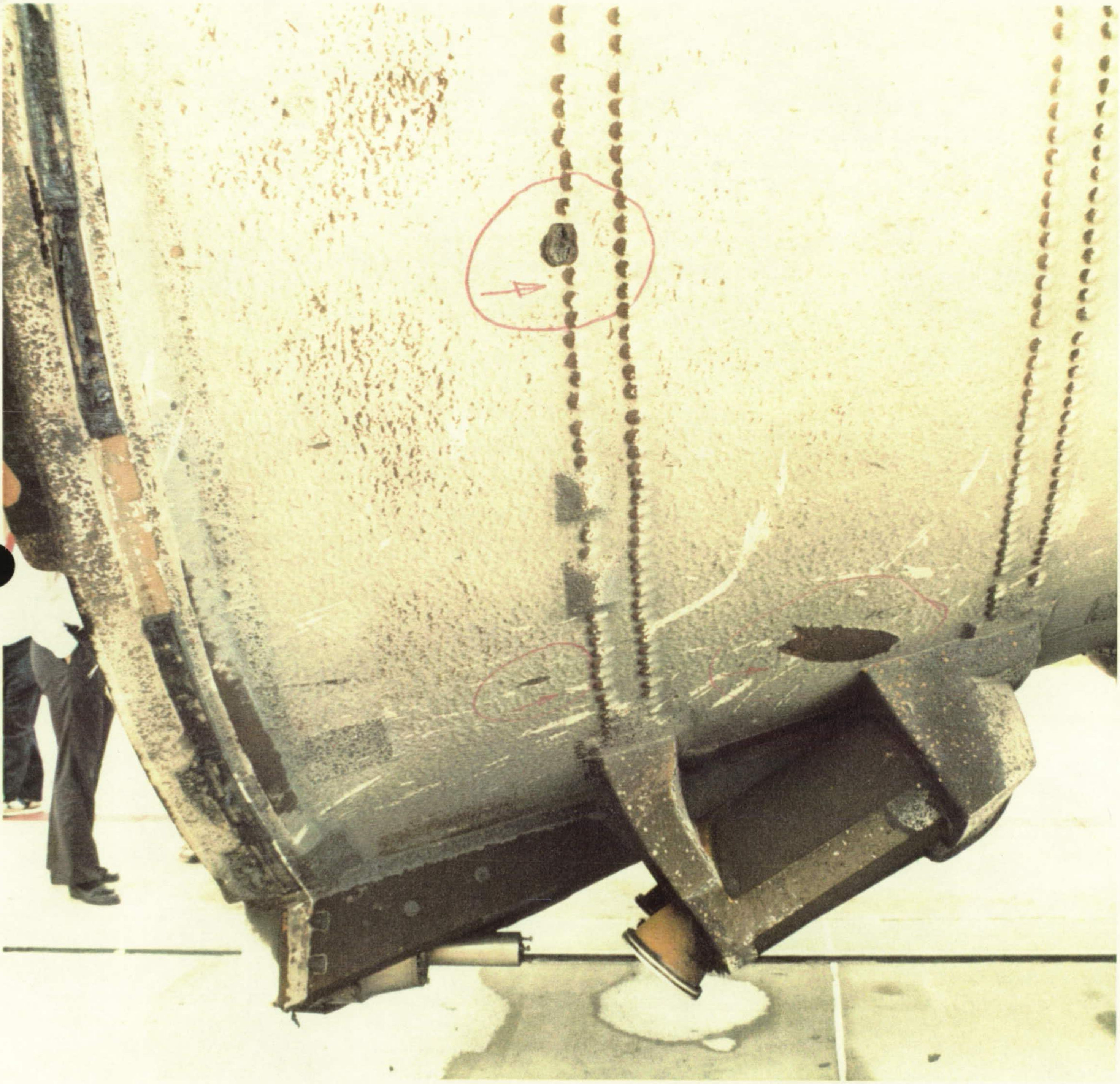


The upper strut fairing (milk can) was missing a 7" x 3" piece of K5NA. The substrate was charred.



Post flight condition of the RH aft booster. Separation of the aft ET/SRB struts appeared normal. All three aft booster stiffener rings sustained water impact damage.

ORIGINAL PAGE
COLOR PHOTOGRAPH



Three divots, one of which exposed two fastener head covers, occurred on the aft skirt acreage TPS near the location of the booster separation motors (BSM's).

Close-up view of the 13" x 5" MSA-2 divot. Post flight analysis revealed a lack of high heat exposure, but did show signs of debris impacts followed by in-flight erosion. However, no foreign debris particles were detected in the remaining material. The divot most likely occurred during descent since areas of MSA-2 within the divot were peeled upward toward the nosecone and exhibited forward fracture sooting.

This divot exposed two fastener head covers and a small area of substrate. Post flight analysis revealed no foreign debris or high ascent heating effects. The divot was caused by a "smiley" starting aft of the fasteners during descent, which sooted the aft fracture surface before the MSA-2 broke loose.

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS, but had 27 MSA-2 debonds over fasteners and two MSA-2 acreage debonds. There was minor localized blistering of the Hypalon paint along the 395 ring frame (Figure 7). 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.

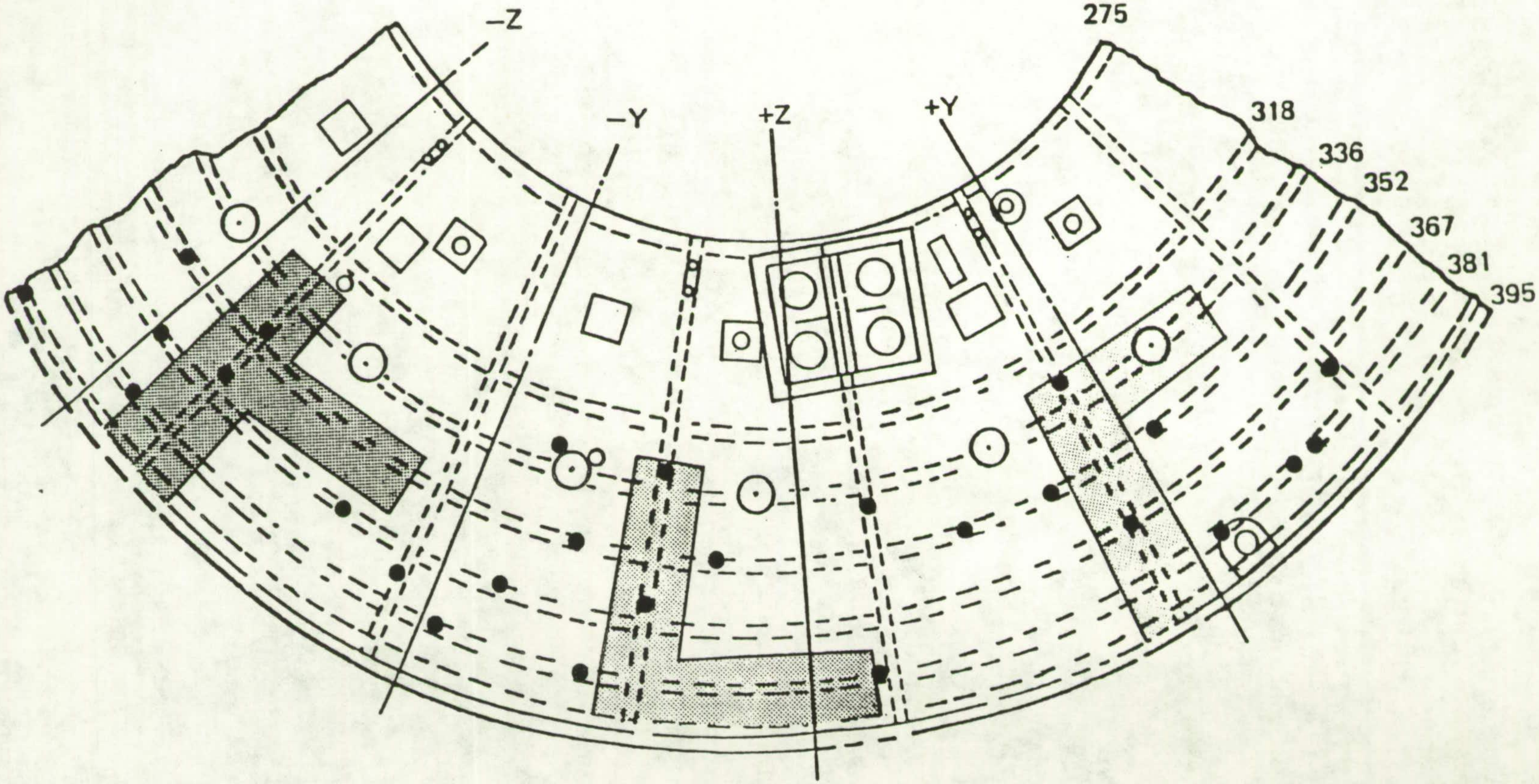
The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

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 (milk can) was missing a 3" x 1" area of K5NA and the substrate was charred. All three aft booster stiffener rings sustained water impact damage. The aft booster forward, center, and aft stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited localized delamination. The acreage TPS on the aft skirt was generally in good condition (Figure 9).

A 6" x 2" piece of EPON shim was lost from HDP #8 aft skirt foot prior to water impact. All four Debris Containment System (DCS) plungers were properly seated. This was the eleventh flight utilizing the optimized link.

Figure 7. **LEFT SRB FRUSTUM**



MISSING TPS

NONE

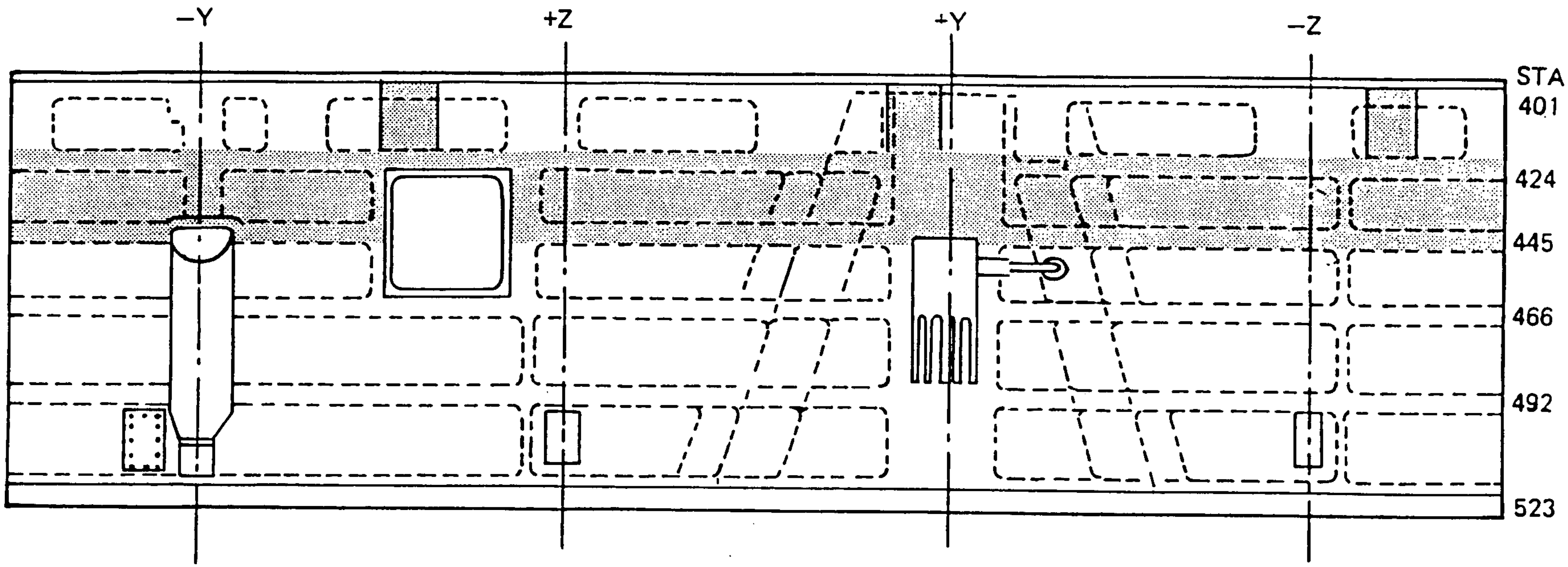
DEBONDS

● 27 OVER FASTENERS

○ 2 ACREAGE

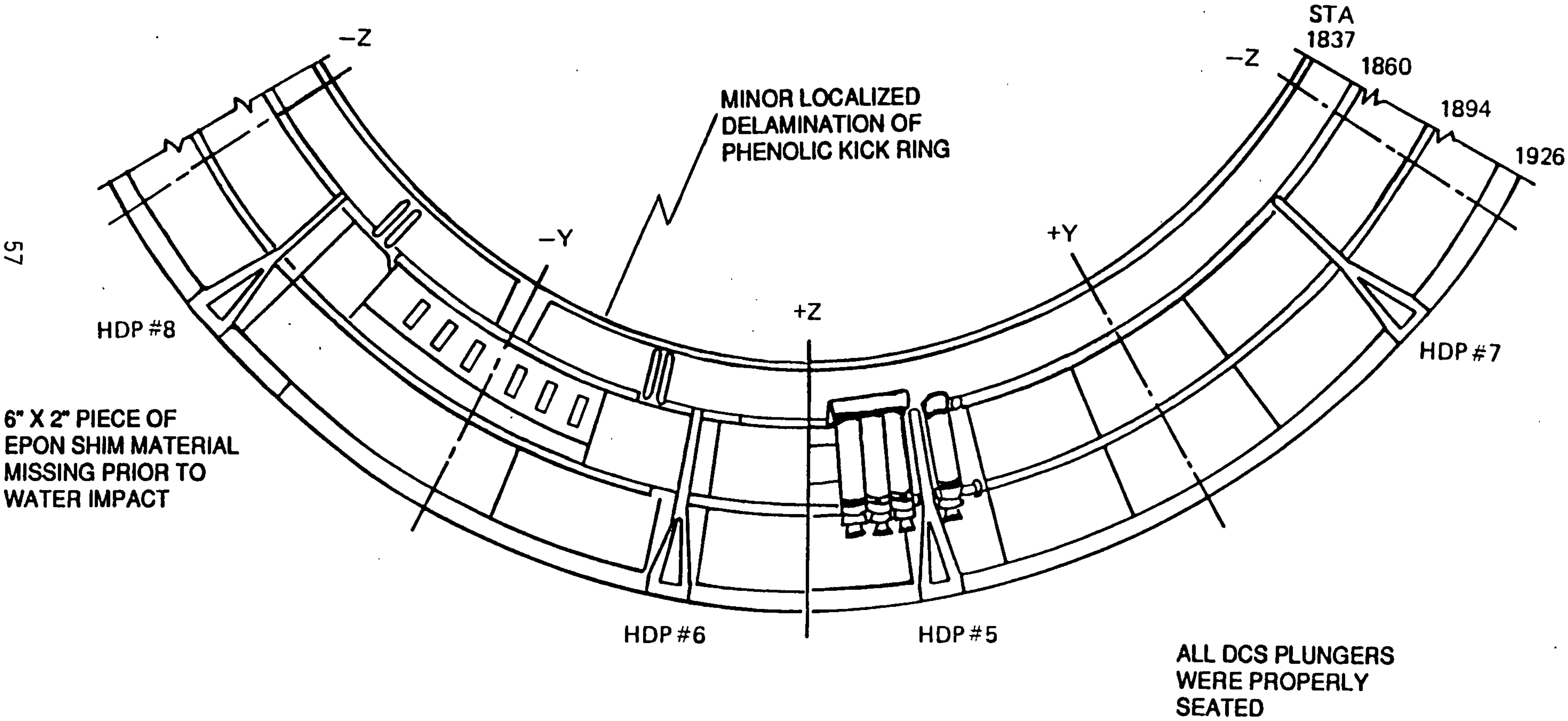
EGG...26E

Figure 8. **LEFT SRB FWD SKIRT**

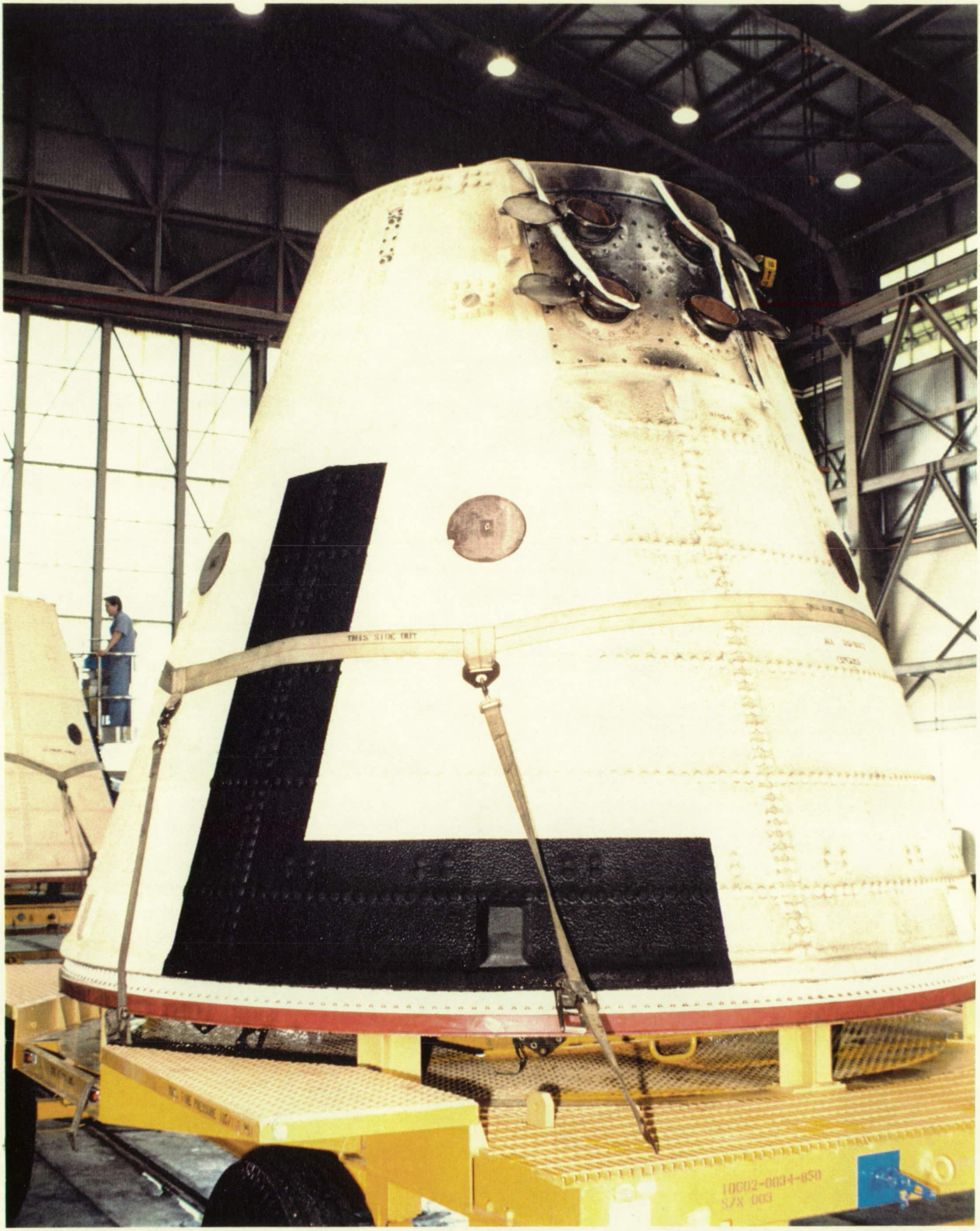


TPS MISSING	DEBONDS
NONE	NONE

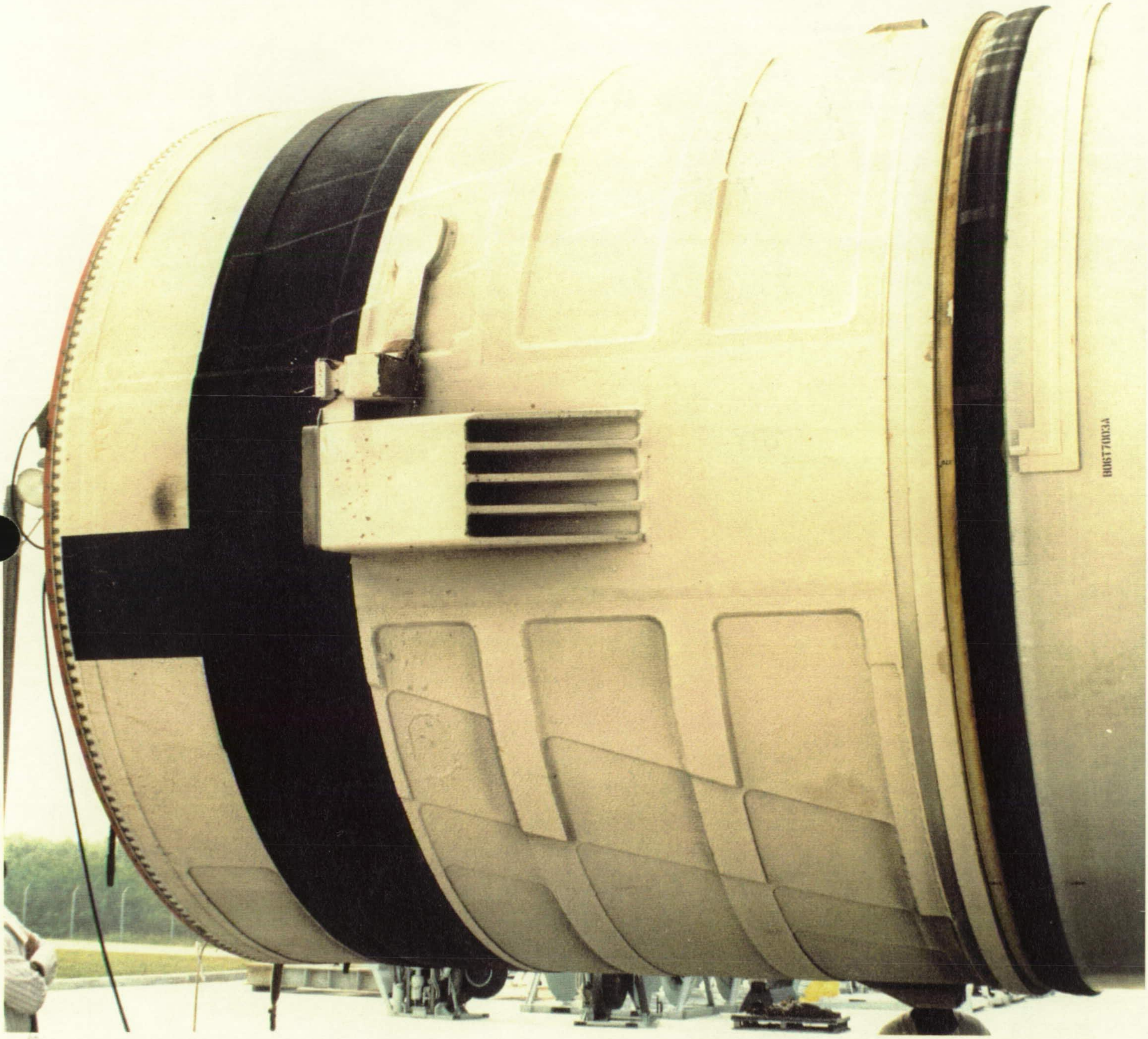
Figure 9. **LEFT SRB AFT SKIRT EXTERIOR TPS**



V-326F

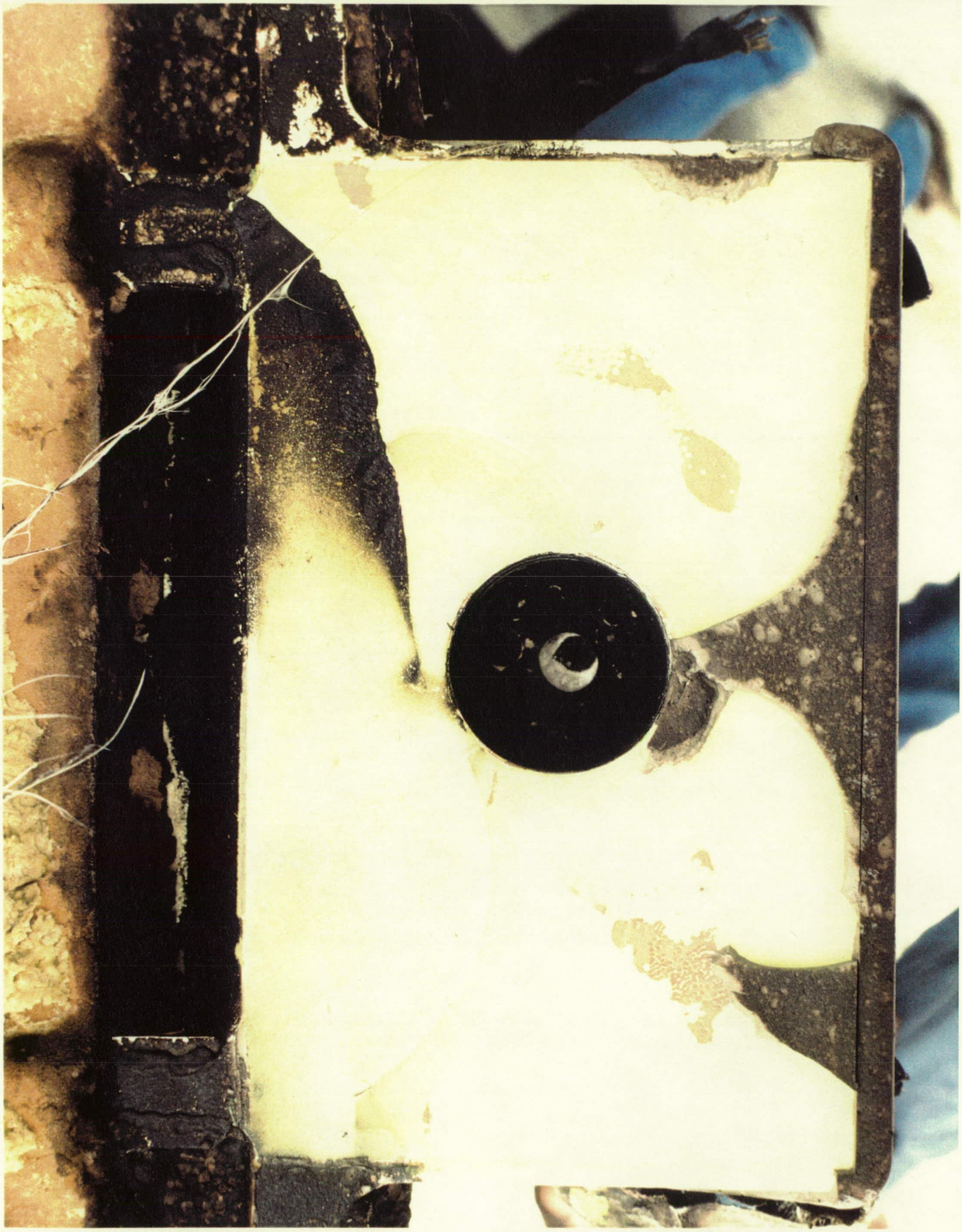


The LH frustum was missing no TPS, but had 27 MSA-2 debonds over fasteners. The BSM aero heat shield covers were locked in the fully opened position.



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. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. All three aft booster stiffener rings sustained water impact damage



A piece of the HDP #8 EPON shim was 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	94	99
4	99	96	99
5	99	94	97
6	99	96	99
7	99	96	99
8	99	96	99

STS-52 was the eleventh 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.

The Instafoam on the forward surface of the RH ETA ring exhibited two rectangular cavities (1.6 x 0.5 x 1.3 inches and 1.3 x 0.4 x 0.7 inches). Samples of adjacent foam were removed and analyzed at MSFC (ref USBI No. BLV-106-92MP). No evidence of any debris or foreign material was found embedded in either cavity. Dark material removed from the bottom of the cavities was determined to be charred Instafoam similar to that found on the exterior foam surface. The report concluded the cavities had experienced a full ascent heat load and were most likely present prior to launch rather than an in-flight occurrence.

MSA-2 adjacent to the two divots just to the -Y side of the single BSM was removed and analyzed at MSFC (ref USBI report No. BLV-107-92MP). The divots did not penetrate the entire thickness of the MSA-2 and no substrate was visible (0.12 inch depth maximum). Microscopic examination revealed a lack of high heat exposure but did show signs of debris impacts followed by in-flight erosion. However, no foreign debris particles were detected in the divots. The report concluded the divots most likely occurred during descent since areas of MSA-2 within the divot were peeled upward toward the nose cone and exhibited forward fracture sooting.

A third MSA-2 divot at station XB-1894 partially exposed two PR1422 fastener head covers. Adjacent MSA-2 was removed and analyzed at MSFC (ref USBI report BLV-108-92MP). The substrate was exposed in a small area of the divot. Sooting on the aft fracture surface of the divot was darker than the forward surface. No foreign debris particles or high ascent heating effects were detected in the fracture surfaces. The report concluded the divot was caused by a "smiley" starting aft of the fasteners during descent, which sooted the aft fracture surface before the MSA-2 broke loose.

SRB Post Launch Anomalies are listed in Section 9.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-102 (Columbia) was conducted on November 1-2, 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 290 hits, of which 16 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 35 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42 which had damage from known debris sources), indicates that the total number of hits is much greater than average but the number of hits one inch or larger is less than average. Figures 10-13 show the TPS debris damage assessment for STS-52.

The Orbiter lower surface sustained a total of 152 hits, of which 6 had a major dimension of one inch or greater. The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

The following table breaks down the STS-52 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	6	152
Upper surface	4	83
Right side	3	18
Left side	0	15
Right OMS Pod	0	12
Left OMS Pod	3	10
TOTALS	16	290

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.

All three ET/Orbiter separation devices (EO-1,2, and 3) appeared to have functioned properly. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No flight hardware was found on the runway below the umbilicals when the ET doors were opened.

Figure 10. **DEBRIS DAMAGE LOCATIONS**

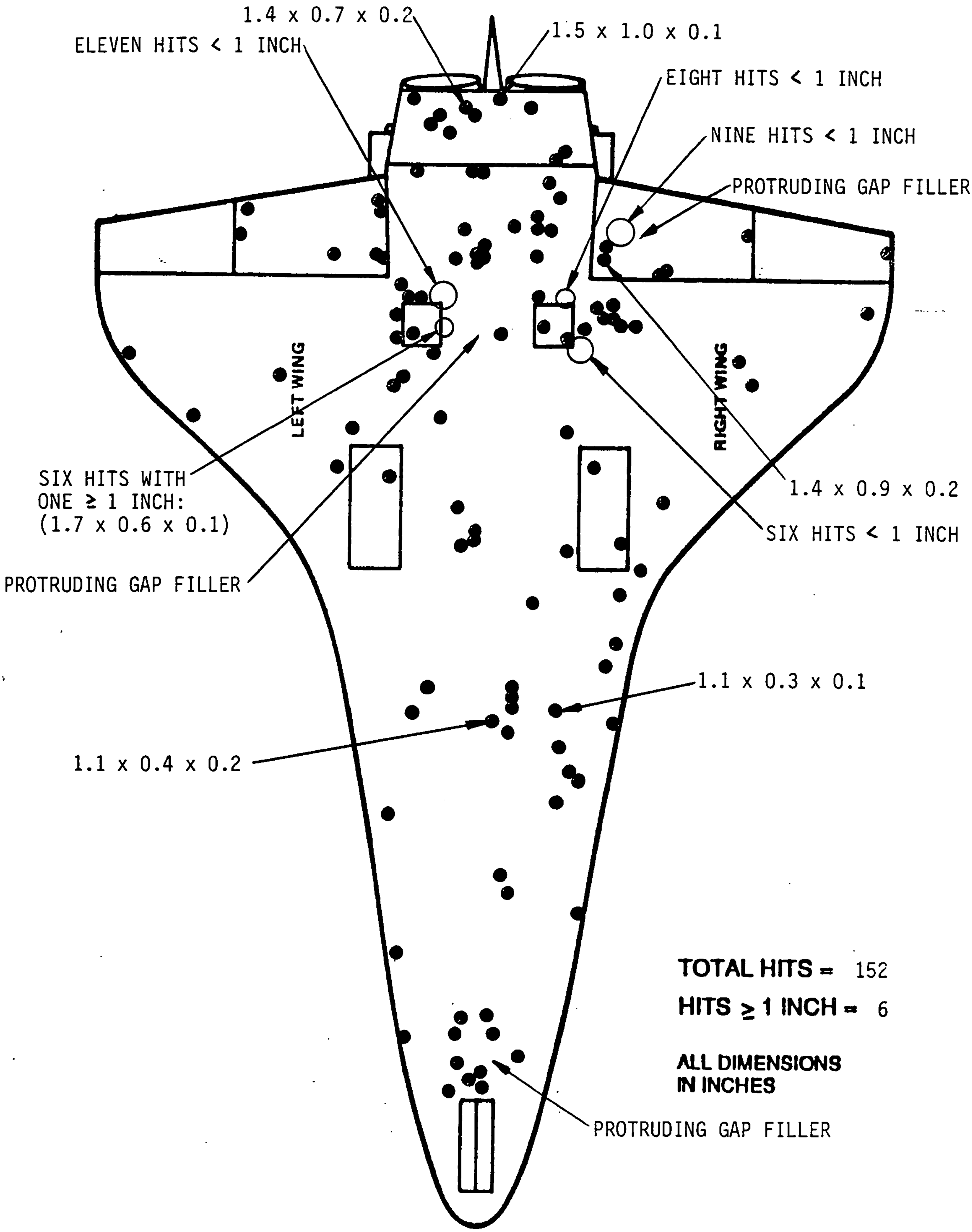


Figure 11. **DEBRIS DAMAGE LOCATIONS**

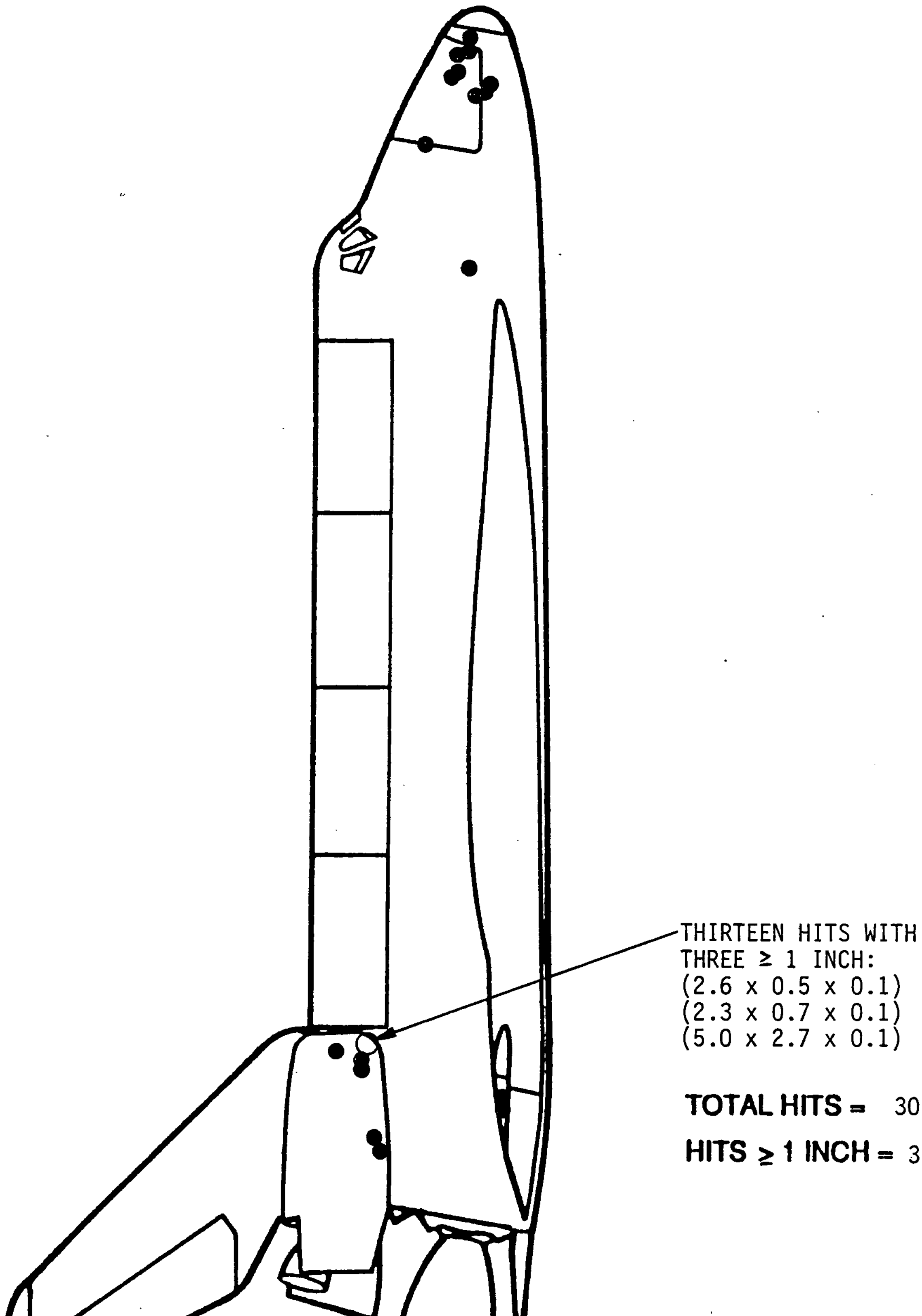


Figure 12. **DEBRIS DAMAGE LOCATIONS**

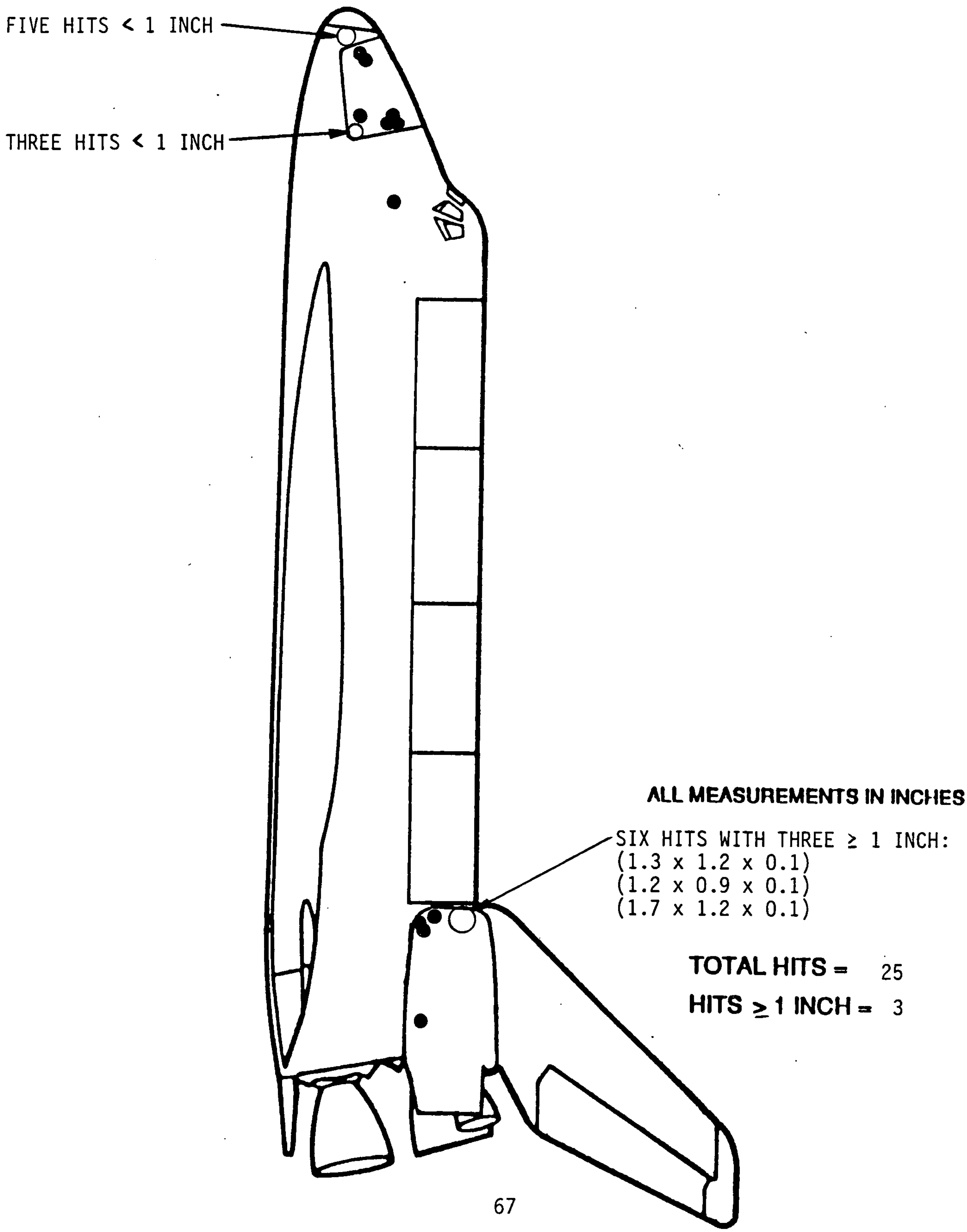
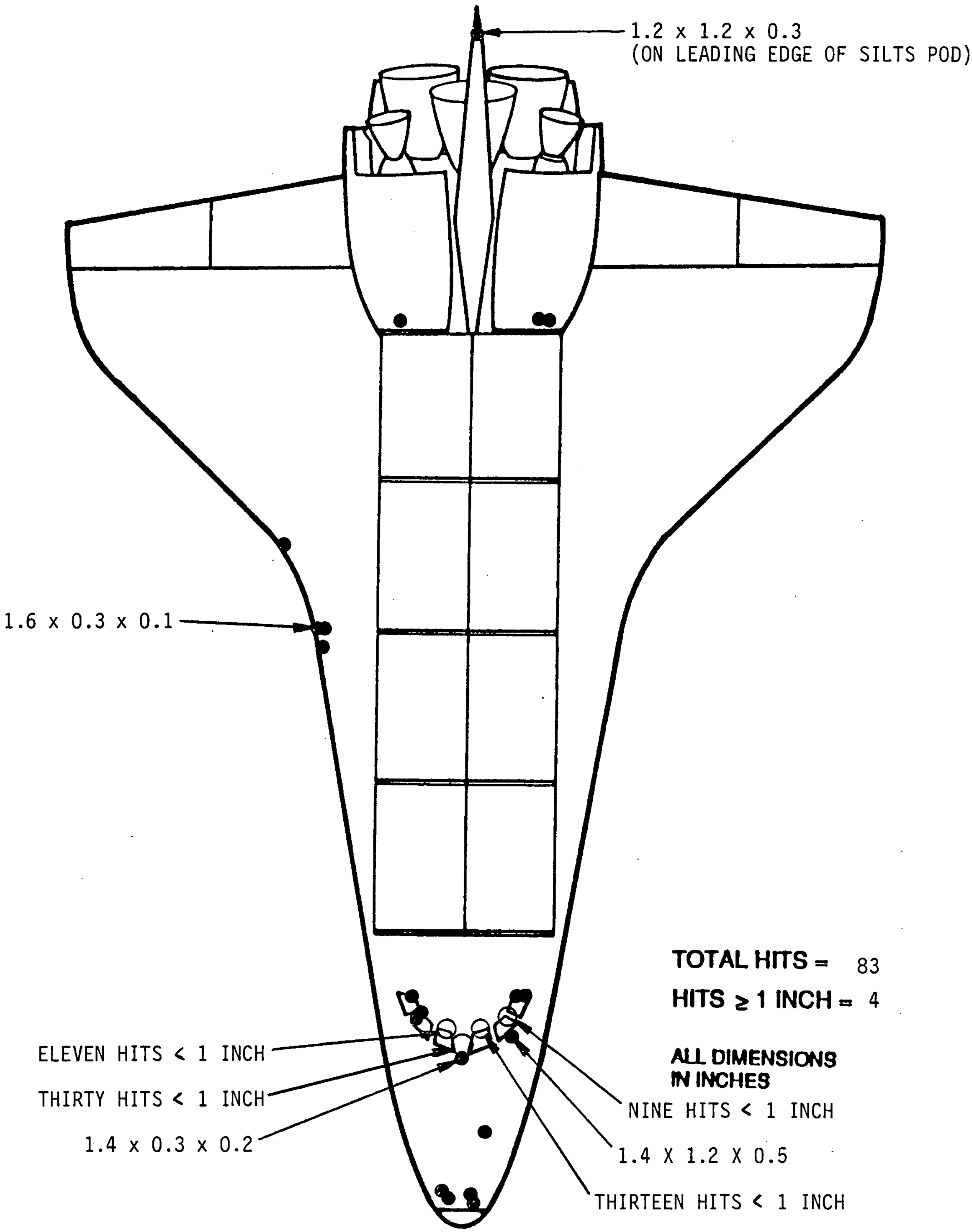


Figure 13. **DEBRIS DAMAGE LOCATIONS**



In general, damage to the base heat shield tiles was typical. However, the majority of tile V070-395093-016 was missing between SSME #2 and #3. This tile, which covers a deactivated calorimeter, sustained an in-plane failure leaving the strain isolation pad and an attached layer (approximately 0.3 inches thick) of densified tile material in the cavity. An In-Flight Anomaly (IFA) was taken to document this discrepancy. In addition to the missing tile, an 8 by 6 by 0.5-inch tile damage site was present on the base heat shield adjacent to SSME #1 (at approximately the 7:00 o'clock position). This damage site appeared to have been impacted by a dense object and may have been caused by the lost tile.

Two Dome Mounted Heat Shield (DMHS) closeout blanket sacrificial panels were missing and two were nearly detached from 2:00 to 4:00 o'clock around SSME #2. All of the remaining DMHS blankets were in excellent condition.

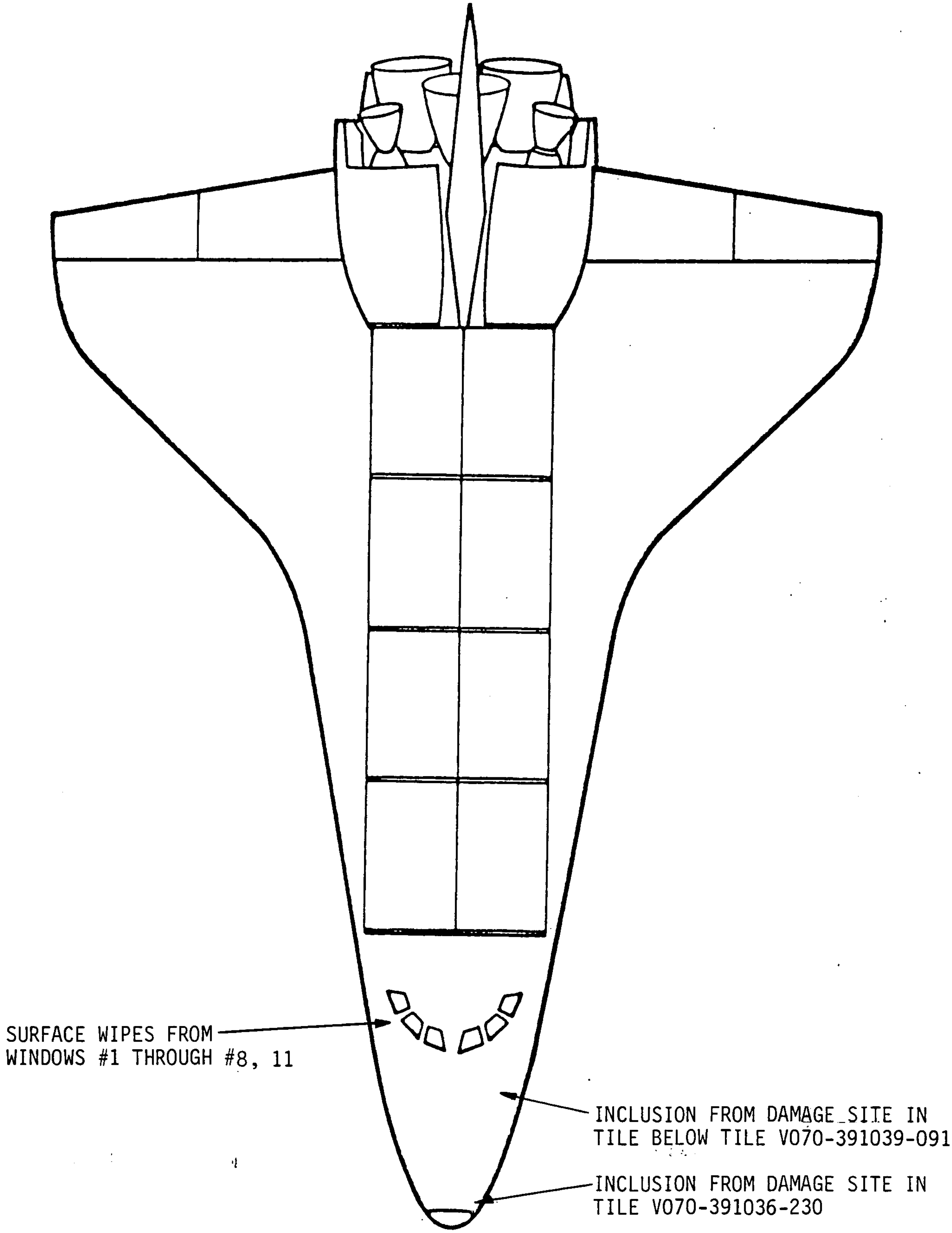
Orbiter windows #2 and #5 exhibited light hazing. Windows #3 and #4 had a few small streaks. Hazing on the other windows was less than usual. Surface wipes have been taken from Windows #1 through #8 and #11 for laboratory analysis (reference section 8.0 for analysis results). A very large number of tile impact sites (seventy with two larger than one inch) were noted on the perimeter tiles around windows #1 through #6. Most all of these hits were small and shallow in depth and may have been caused by RTV used to bond paper covers to the FRCS nozzles, exhaust products from the SRB booster separation motors, ice/TPS debris from the External Tank LO2 tank, or Orbiter TPS fragments (or any combination of the above).

Samples of inclusions found in two tile damage sites on the Orbiter nose were taken for laboratory analysis (reference Figure 14 for sample locations and section 8.0 for analysis results).

Runway 33 was inspected and swept by KSC EG&G SLF personnel on October 31, 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 was a tile gap filler (V070-395052-175). This gap filler originated from the left aft fuselage sidewall.

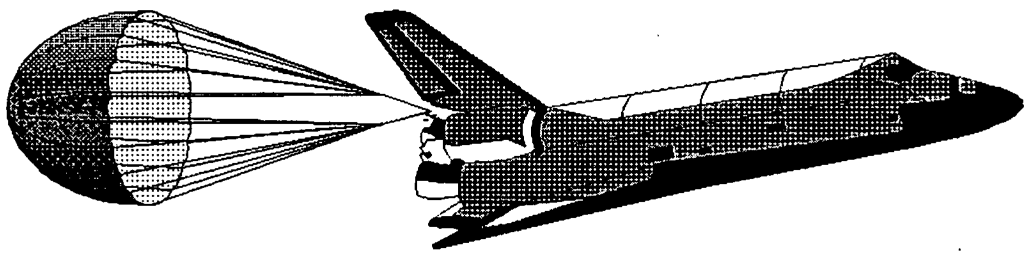
This flight marked the fourth use of the Orbiter drag chute. The drag chute appeared to have functioned nominally. However, a tile on the aft end of the vertical stabilizer stinger was damaged by the chute risers during deployment. Another tile, on the lower (-Z) RH edge of the drag chute compartment opening, was slightly damaged by separation of the chute compartment door. Similar damage has been observed after every previous use of the drag chute. All drag chute hardware was recovered and showed no signs of abnormal operation (reference Figure 15 for recovery locations).

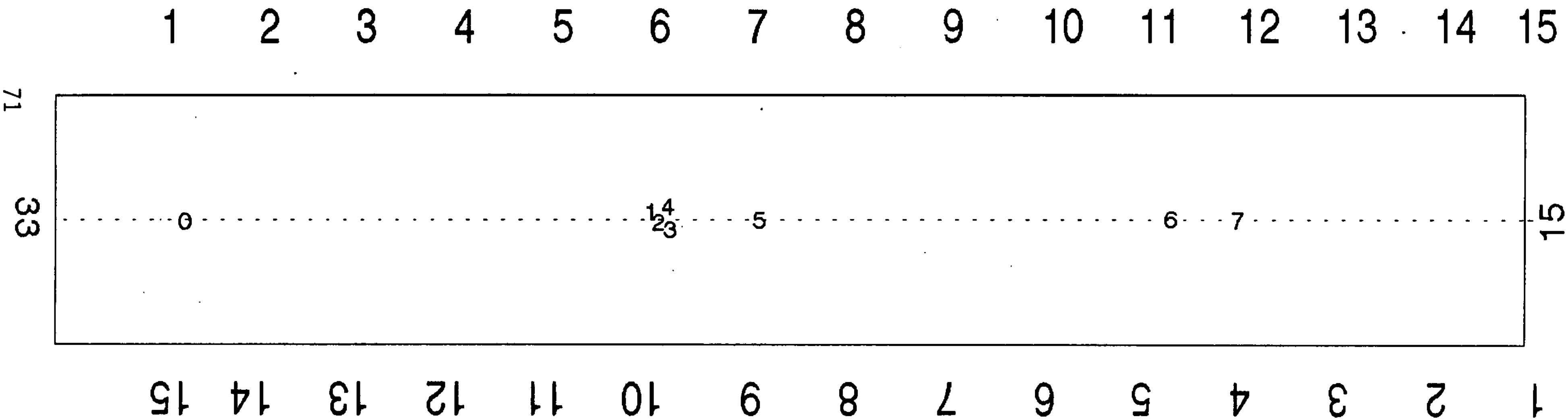
Figure 14. **CHEMICAL SAMPLE LOCATIONS**



RECOVERY LOCATIONS OF DRAG CHUTE COMPONENTS

Figure 15.





0 (MLG TOUCHDOWN): 1080'
1 (MORTAR COVER): 5900', 15' L OF C/L
2 (SABOT): 5980', ON C/L
3 (DOOR): 6020', 50' R OF C/L
4 (PILOT CHUTE): 6020', 30' L OF C/L
5 (NLG TOUCHDOWN): 6949'
6 (MAIN CHUTE): 11050', ON C/L
7 (HEEL STOP): 11788'

STS-52
OV-102 COLUMBIA
11/1/92

A portable Shuttle Thermal Imager (STI) was used to measure the surface temperatures of three areas on the Orbiter (per OMRSD V09AJ0.095). Twenty-eight minutes after landing the Orbiter Reinforced Carbon-Carbon (RCC) nosecap was 183 degrees Fahrenheit (F). Twenty-six minutes after landing the RH wing leading edge RCC panel #9 was 144 degrees F, and panel #17 was 132 degrees F (reference Figure 16).

In summary, the total number of Orbiter TPS debris hits was much greater than average while the number of hits one inch or larger was less than average when compared to previous missions (reference Figures 17-19). The cause(s) for the much higher than usual total number of hits (in particular, the seventy hits around the perimeter of the forward facing windows) is still being assessed. It should be noted however, that the vast majority of these hits were very small and do not present a significant refurbishment issue.

One factor that may be contributing to Orbiter debris damage is vehicle age. OV-102 has shown an increasing trend in the total number of debris hits sustained during each flight. This upward trend may be due to the effects of age on Orbiter TPS materials. Original and repaired TPS materials may become weak/loose due to the effects of thermal cycling and exposure to vibration/loading, creating potentially damaging debris. Post landing debris damage sustained by OV-102 during the last six flights is shown in Figure 20.

Orbiter Post Launch Anomalies are listed in Section 9.

Figure 16. **STS-52 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

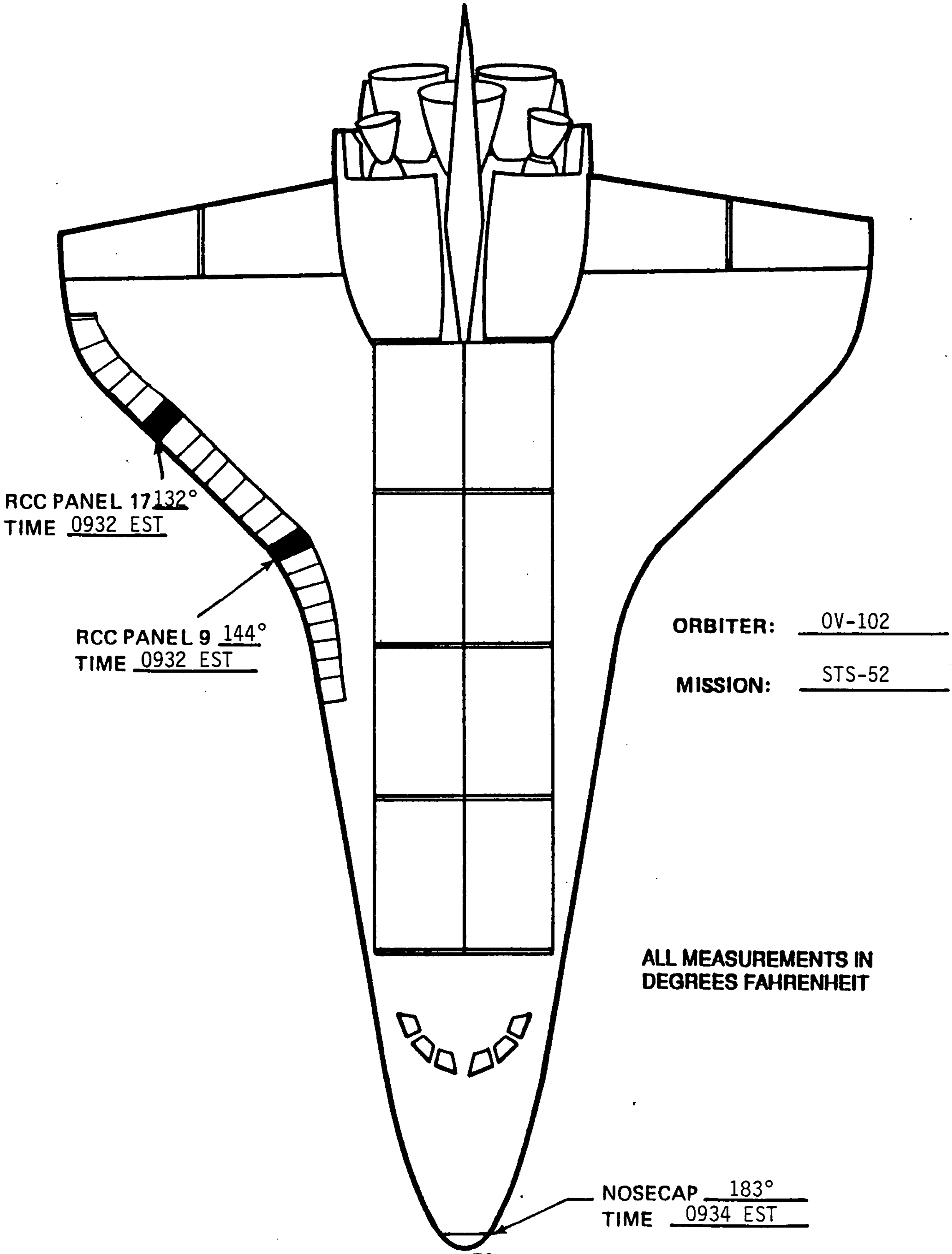


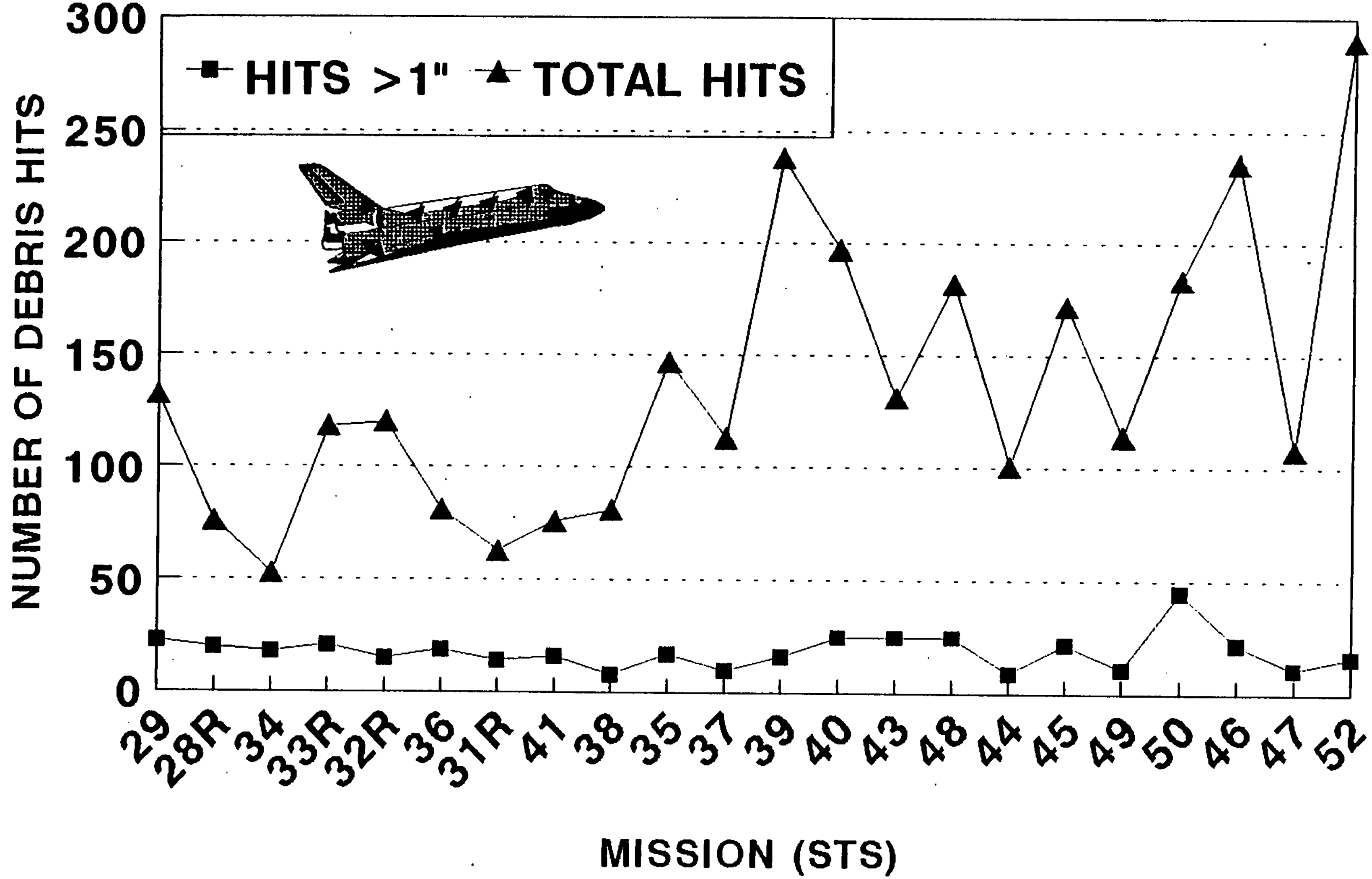
FIGURE 17: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
AVERAGE	15.0	90.4	22.4	125.0
SIGMA	7.6	46.6	11.1	56.1
STS-52	6	152	16	290

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-52

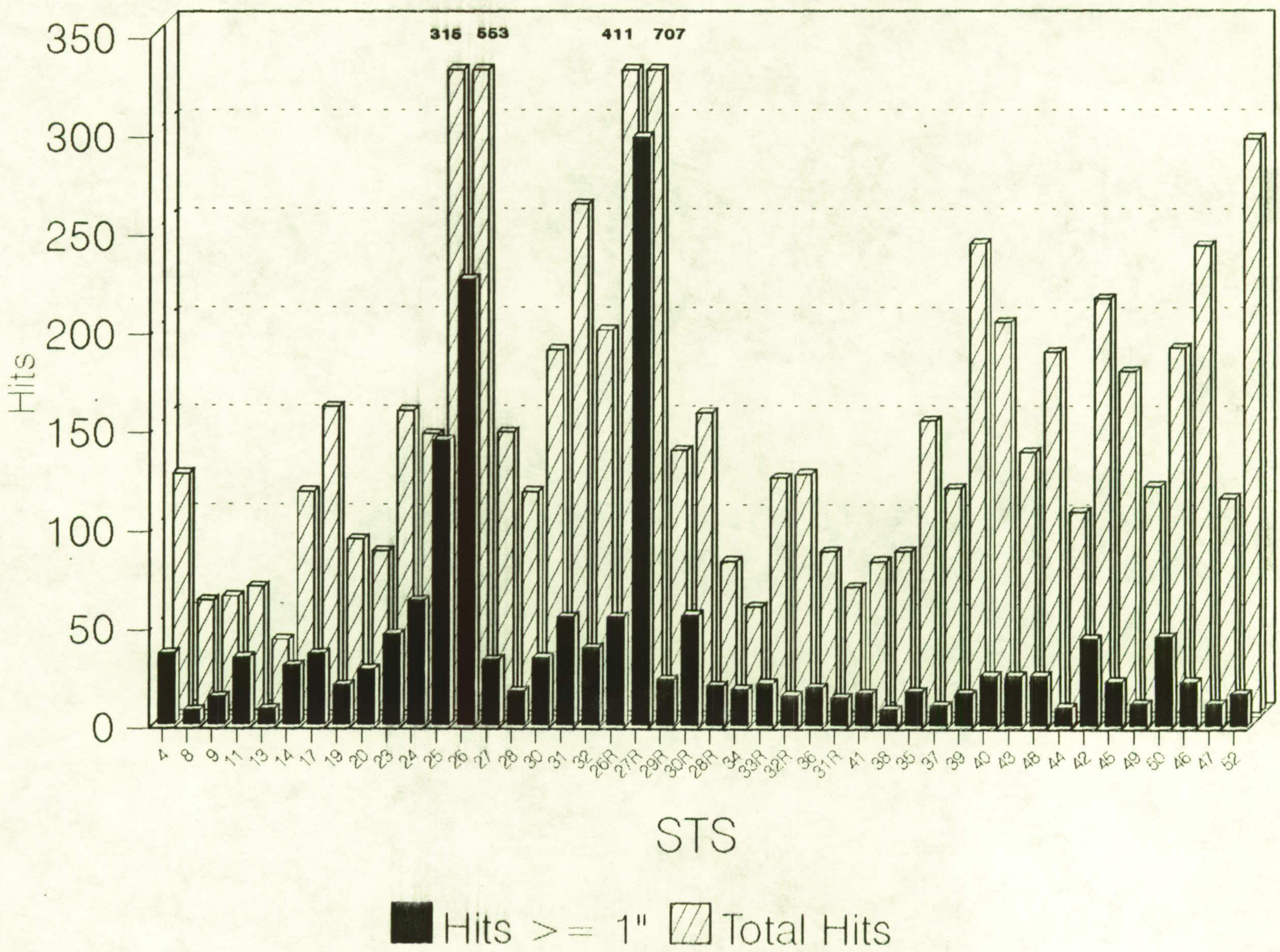
Figure 18.



EXCLUD MISSIONS STS-30R AND 42 WHICH EXPERIENCE SIGNIFICANT DAMAGE FROM KNOWN DEBRIS SO RCES

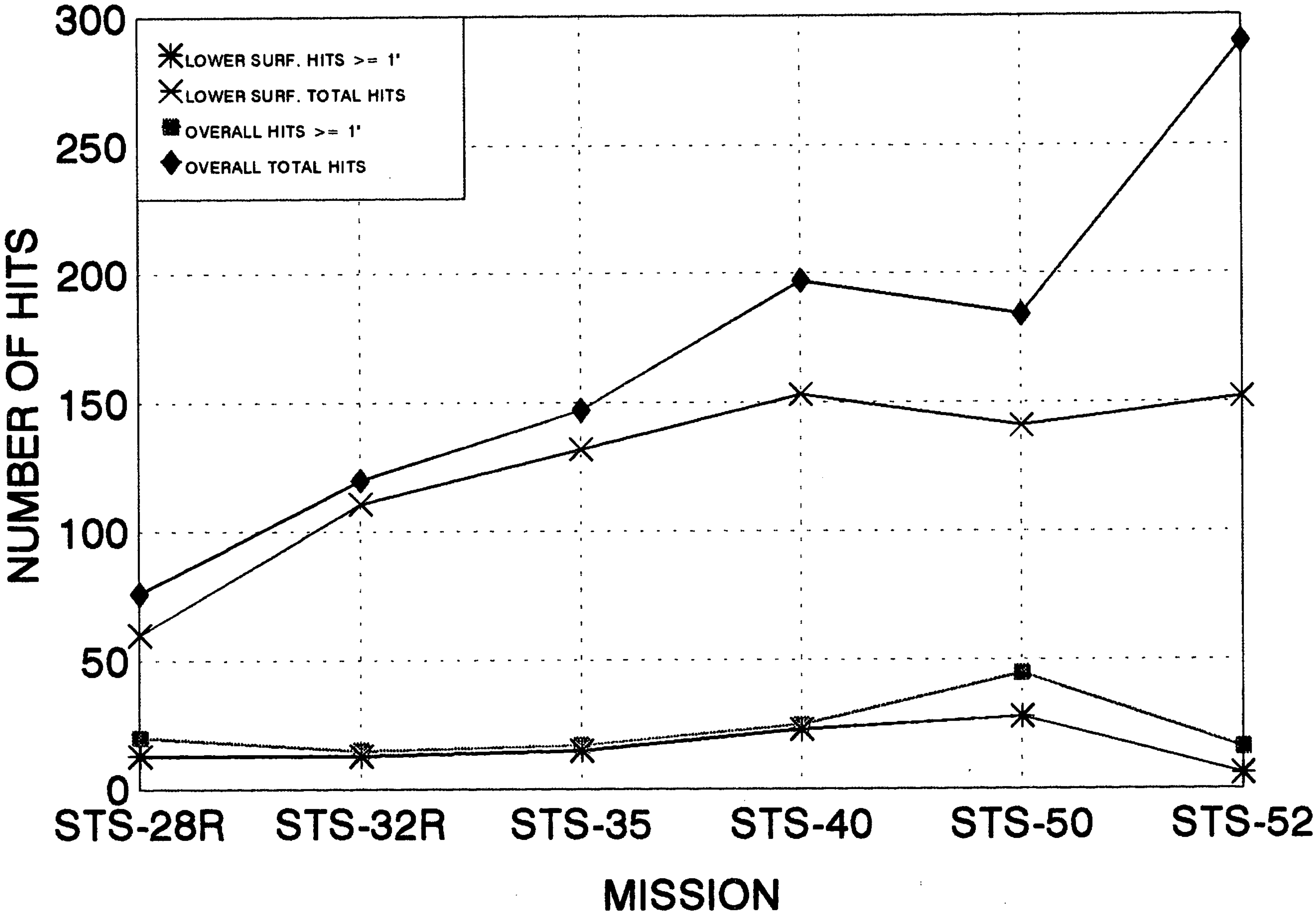
COMPARISON TABLE

Figure 19.

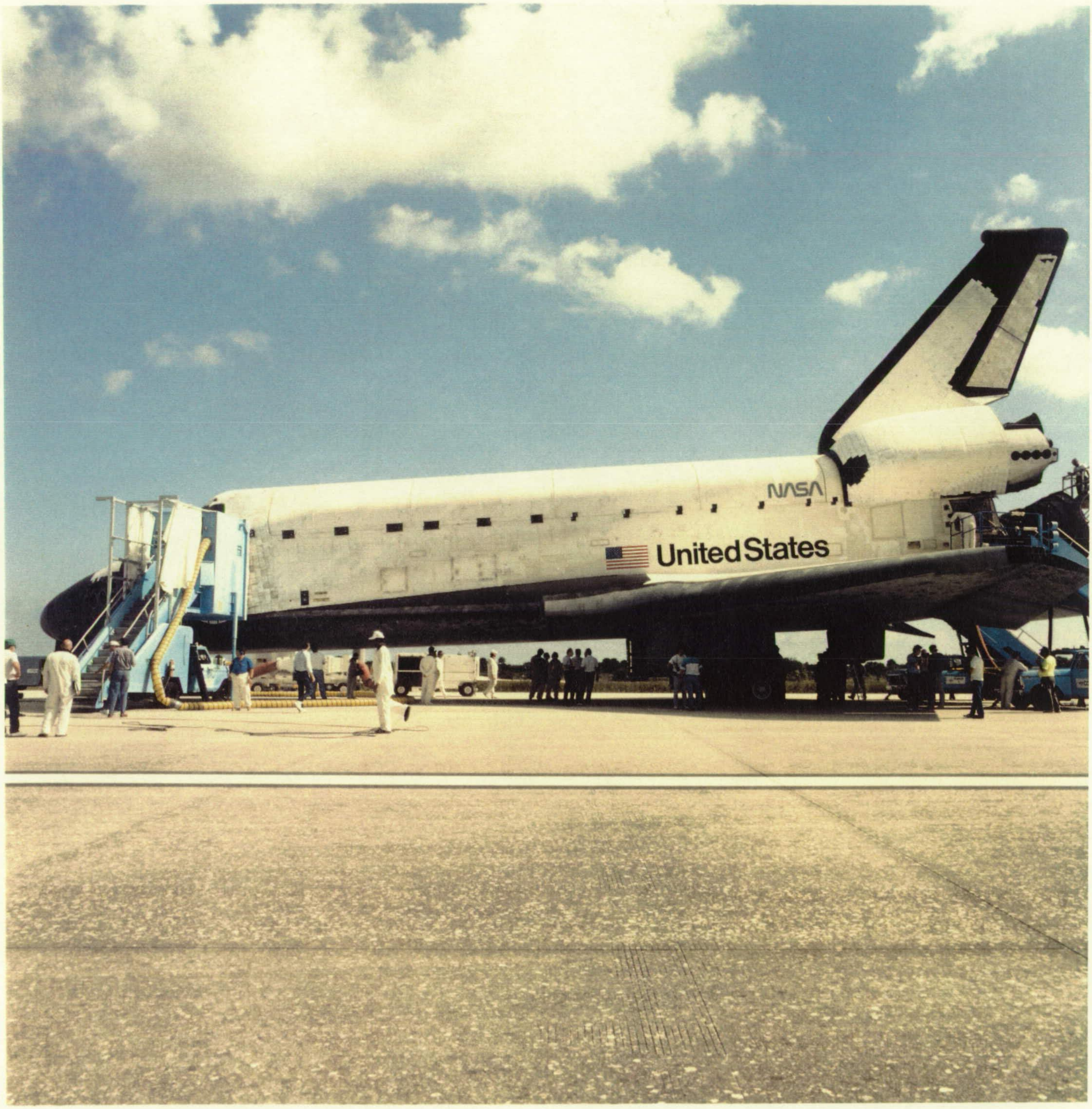


0V-102 POST LANDING DEBRIS DAMAGE

Figure 20.

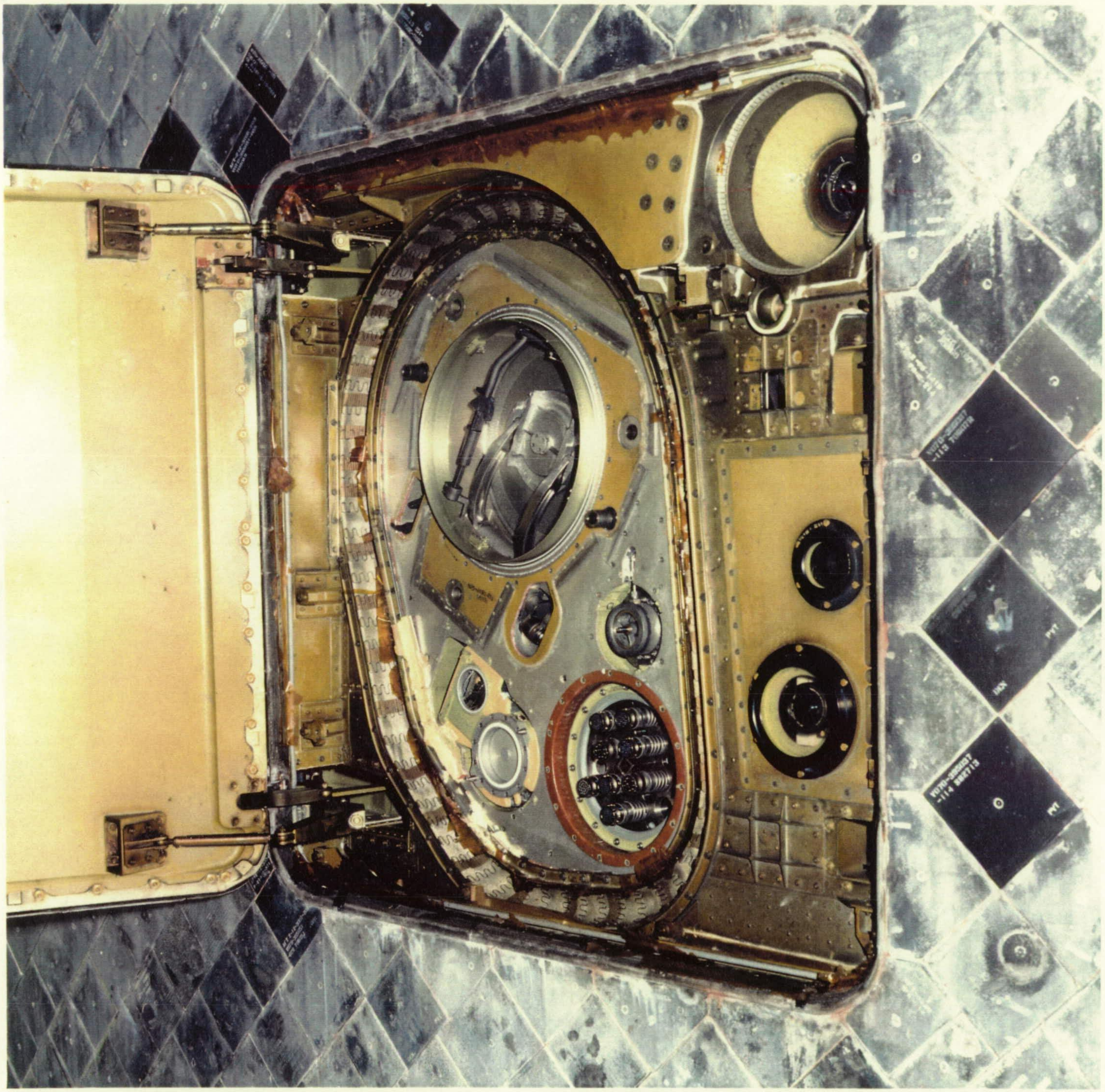


OV-102 Columbia landed at the Kennedy Space Center
Shuttle Landing Facility Runway 33 on 1 November 1992

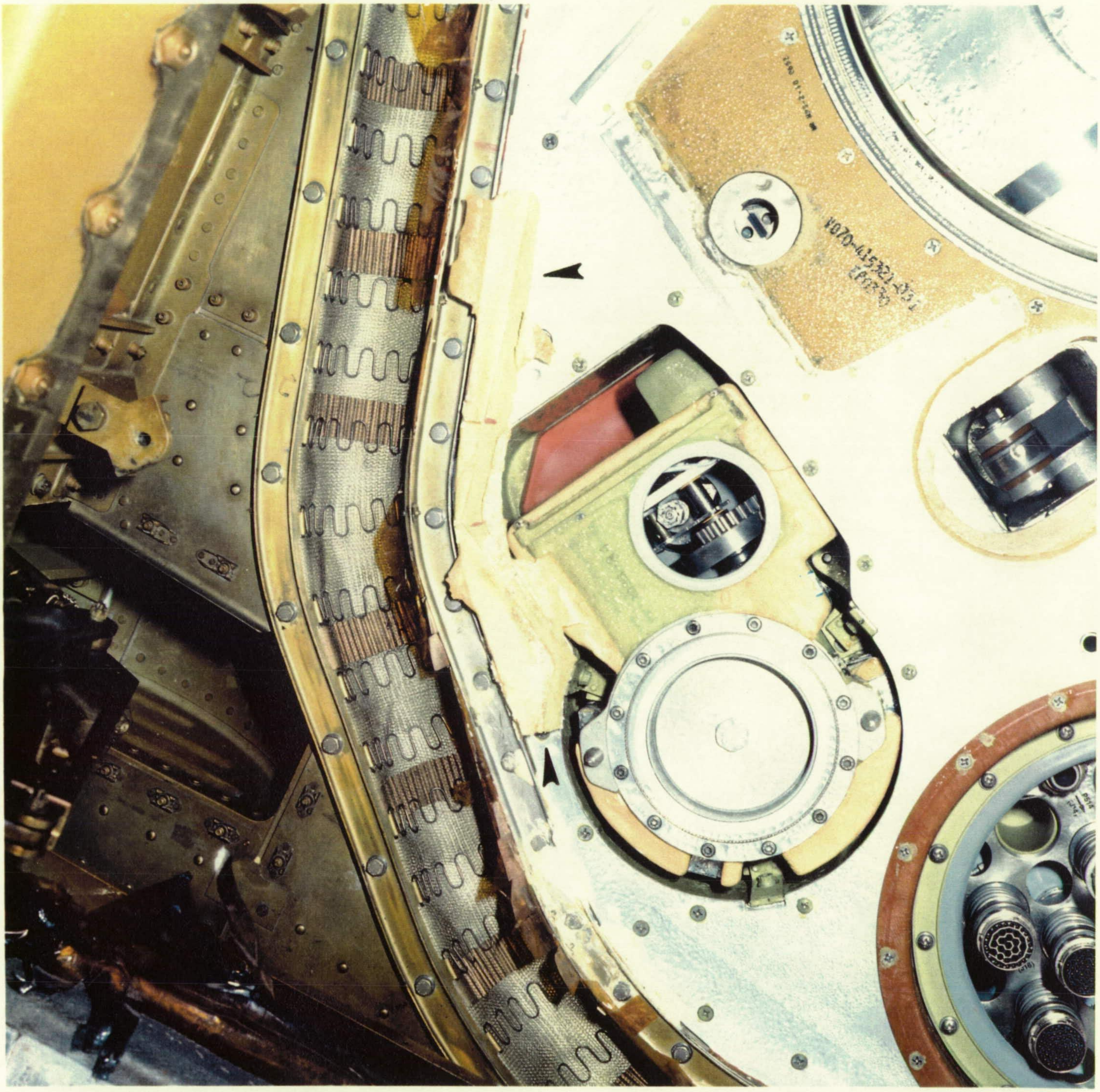


Overall view of Orbiter left side

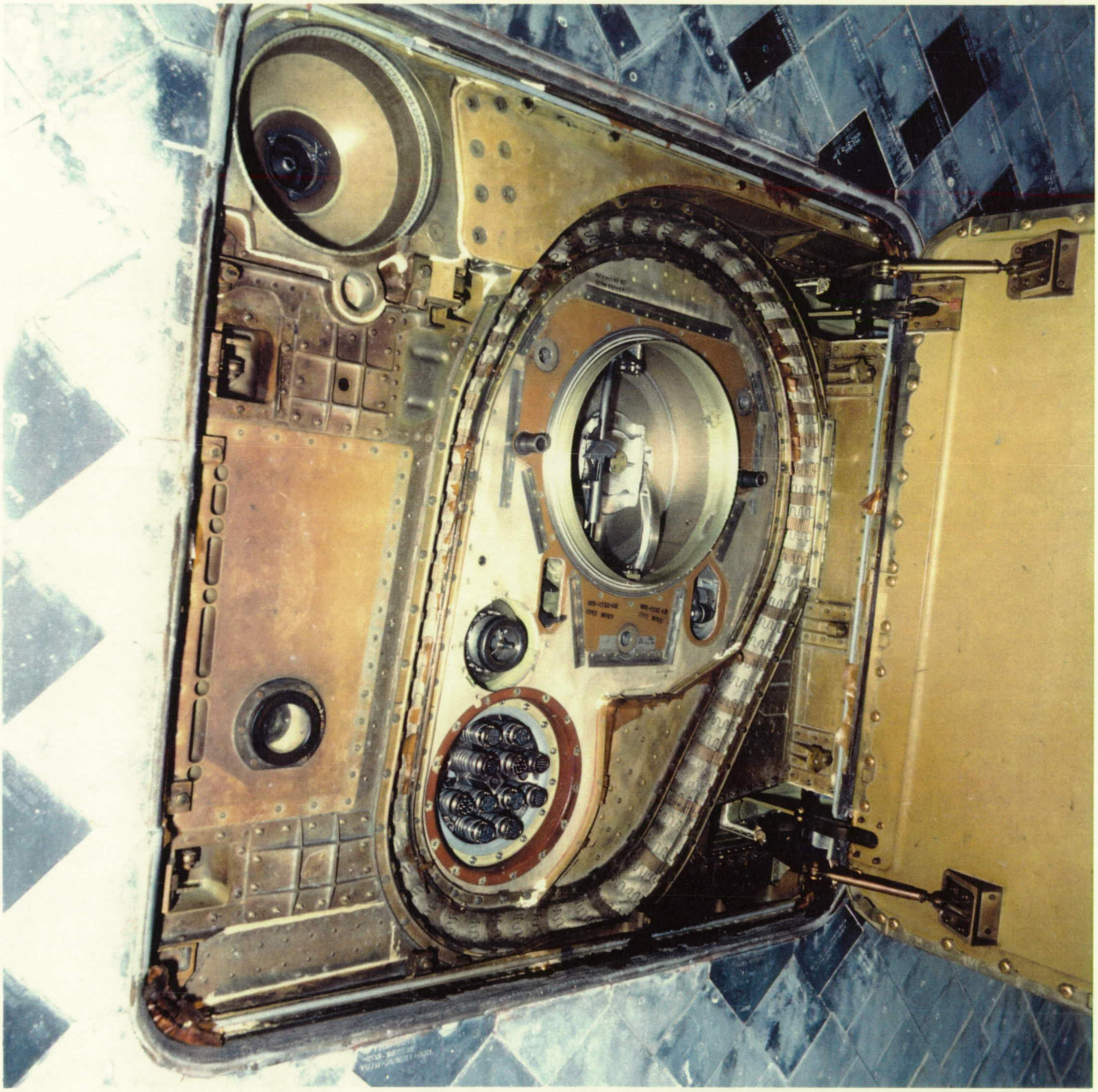
The Orbiter lower surface tiles sustained a total of 152 hits, of which six had a major dimension of 1-inch or greater. The distribution of tile damage hits does not suggest a single source of ascent debris, but indicates a shedding of ice and/or TPS debris from random sources.



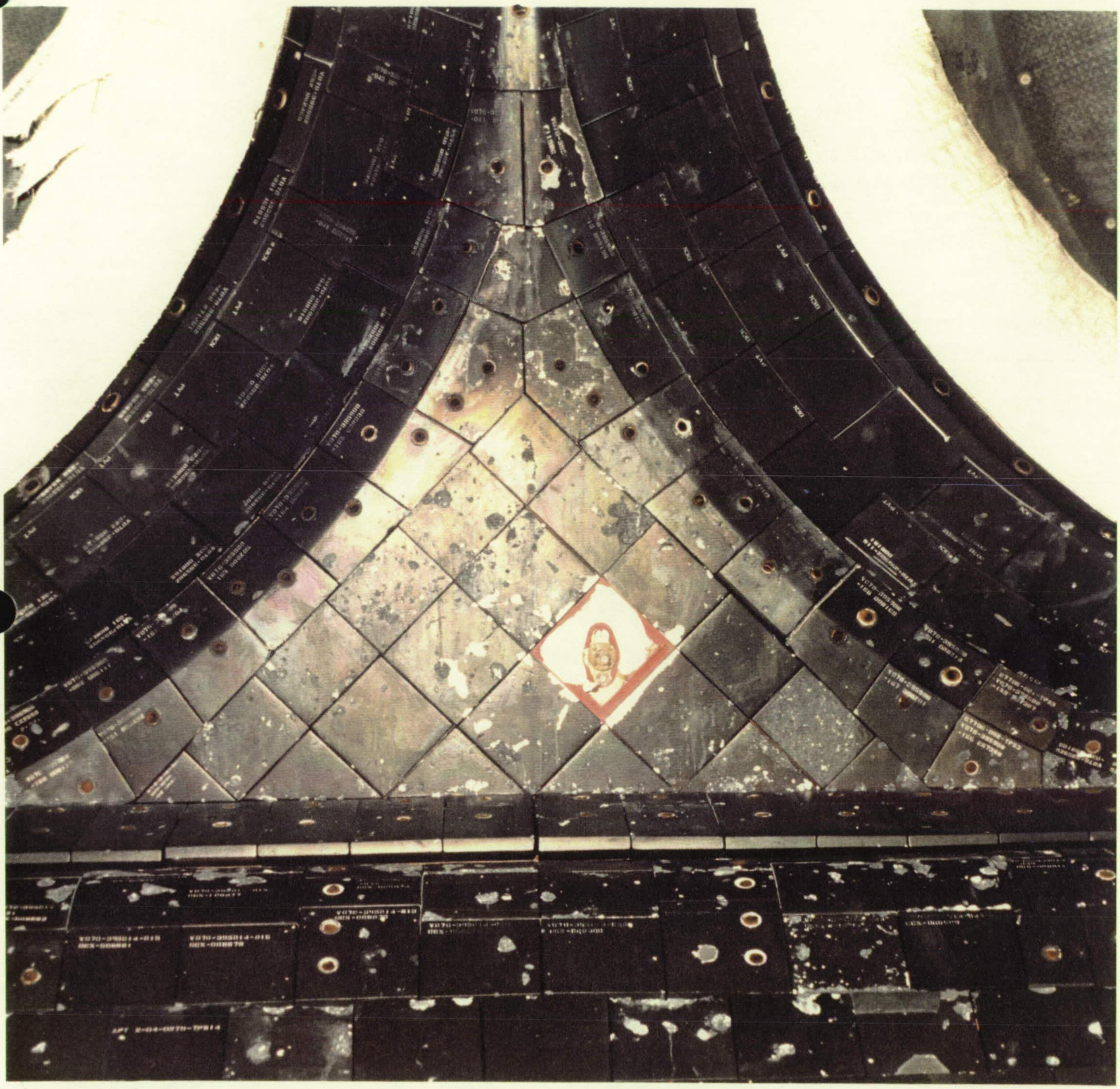
Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.



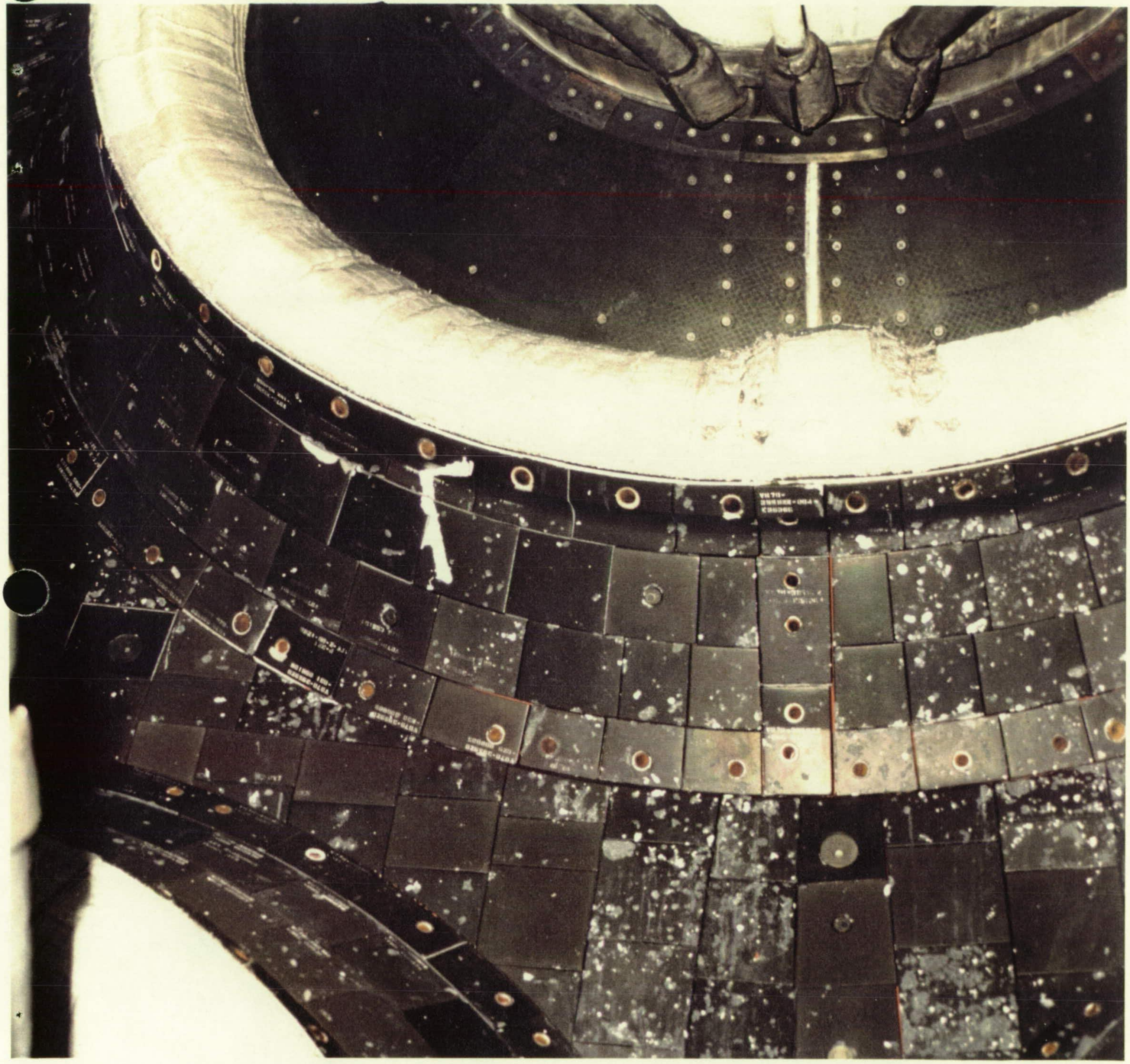
A section of the ET/ORB LH2 umbilical purge seal and closeout foam was still attached to the interface plate/disconnect. The missing section was visible in the separation camera films.



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



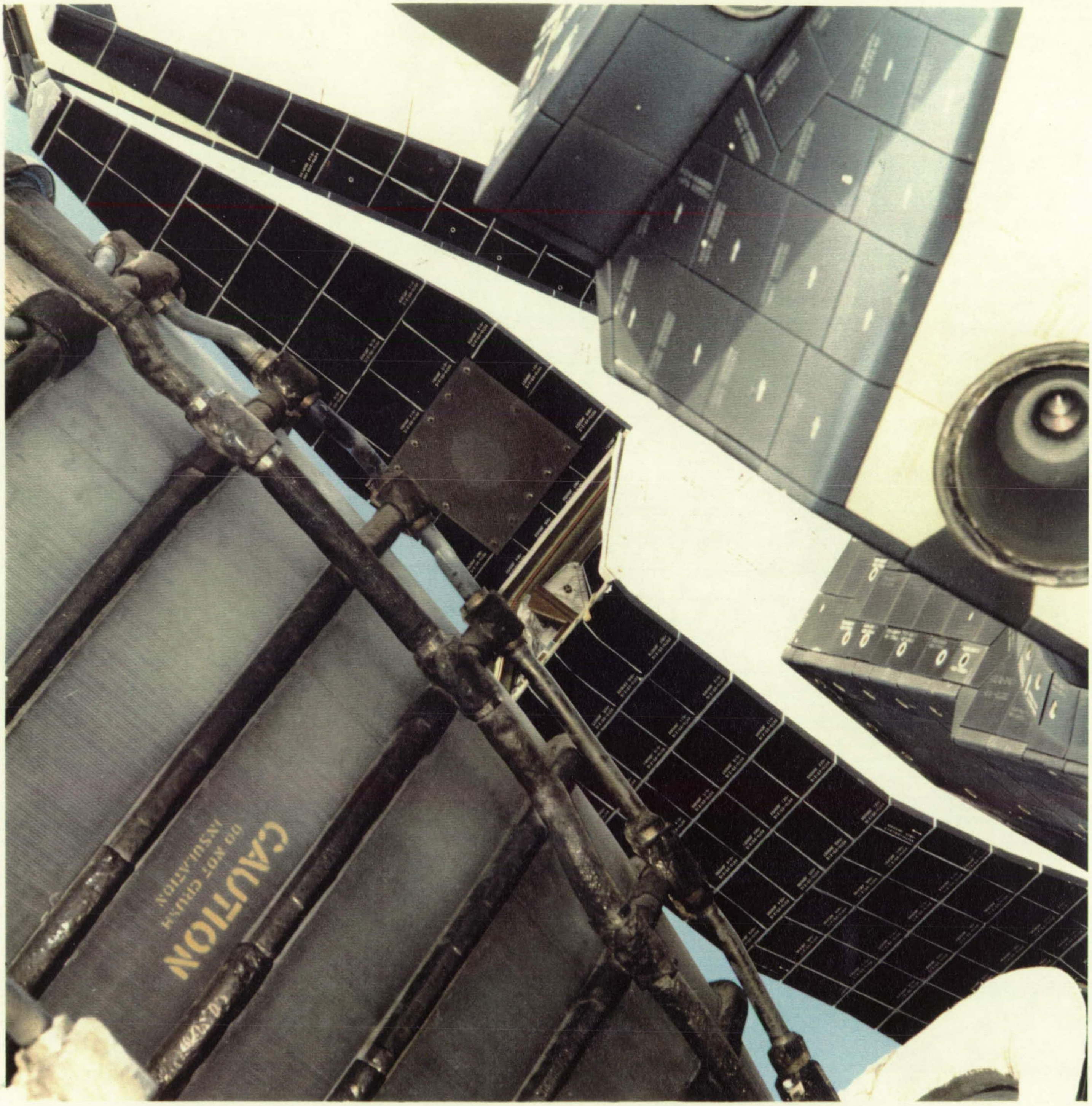
The majority of tile V070-395093-016 was missing from the base heat shield between SSME #2 and #3. This tile, which covered a calorimeter, sustained an in-plane failure leaving the strain isolation pad (SIP) and an attached layer of densified tile material in the cavity.



An 8" x 6" x 0.5" tile damage site was present on the base heat shield adjacent to SSME #1 (at approximately the 7:00 o'clock position). This damage site appeared to have been caused by a dense object and may have been hit by the lost tile between SSME #2 and #3.

Hazing on the Orbiter windows was light and considered to be less than usual. A large number of tile impact sites (72 with 2 larger than 1-inch) occurred on the perimeter tiles around the forward facing windows. Most of the hits were small and shallow in depth.

Inspection of Runway 33 immediately after landing revealed a tile gap filler from the left aft fuselage sidewall.



Fourth use of the Orbiter drag chute occurred normally. A tile on the lower (-Z) right edge of the drag chute compartment opening was slightly damaged by separation of the chute compartment door. Similar damage has been observed after every previous use of the drag chute.

8.0 DEBRIS SAMPLE LAB REPORTS

A total of eleven samples were obtained from OV-102 Columbia during the STS-52 post landing debris assessment at Kennedy Space Center (ref. Figure 14). The eleven submitted samples consisted of 9 window wipes (Windows 1-8 and 11) and 2 samples from HRSI tile damage sites. 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. Debris 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-rich tile, insulation glass fibers
3. Paints, primer, rust
4. Organics
5. Earth compounds

Debris analysis provides the following correlations:

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

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

3. Paints and primer are of flight hardware/facility/GSE origin; rust is an SRB BSM exhaust residue.

4. Organics are being analyzed by chemical fingerprint (Infrared Spectroscopy) method; results are pending. This detailed process is more difficult due to small sample quantity.

5. Earth compounds (alpha-quartz, calcite, and salt components) originate from the landing site.

Orbiter HRSI Tile Damage Sites

Results of the Orbiter HRSI tile damage site samples indicated the presence of the following materials:

1. Dense and fibrous tile material
2. Dense Silicon Carbide
3. Paint
4. Earth compounds

Debris analysis provides the following correlations:

1. Dense and fibrous tile material originate from Orbiter thermal protection system (TPS)

2. Dense Silicon Carbide was evaluated by Orbiter TPS engineering and determined the origin to be OML coating of gap filler. This material is applied in liquid form to the exposed edge of gap filler for heat protection.

3. Paint is of flight hardware/facility/GSE origin

4. Earth compounds (calcite and salt components) originated from the landing site

STS-47 Organic Analysis

Results of the STS-47 Organic Analysis indicated the presence of the following materials:

1. Polymeric
2. Rubbery
3. Fibrous

Debris analysis provides the following correlations:

1. Polymeric materials included items with amide, polyamide, aromatic polyamide, and cellulosic characteristics. This variety is similar to that observed in STS-46 samples and appear to originate from Orbiter window protective covers

2. Rubbery materials were found to be methyl silicone, as in red RTV, and a calcium carbonate filled adhesive/ sealant most likely from the protective window covers.

3. Fibrous material detected in this sampling set were cellulosic in nature and probably of sample cloth origin.

Conclusions

The STS-52 mission sustained Orbiter tile damage to a greater than average degree. However, 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, landing site products, organics, and paint. Window polish residue, a material that has been previously detected, was not observed in this mission's chemical sampling results.

The variety of residuals attributed to known sources did not seem to change significantly when compared to previous sample data (reference Figure 21). Included in this report are the results of the STS-47 organic analysis. The results of this analysis are similar to that of previous missions in that new entries do not appear to be related to a debris problem.

A new finding in one of the two HRSI tile damage site samples was the presence of Silicon Carbide. This material was evaluated by KSC Orbiter TPS engineering and is believed to originate from the OML gap filler coating. Additional laboratory testing is planned to characterize the residual deposits of the TPS materials.

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

Figure 21. Orbiter Post-Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
42	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint		Metallics - BSM Residue (SRB) Tile, Tile Coating (ORB) Salt (Landing Site) Paint	Organics	RH Fuselage - Tile Coating (ORB)
44	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insullation 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) Insullation 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) Insullation 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) Insullation 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) Insullation 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 21. Orbiter Post-Landing Microchemical Sample Results

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

Figure 21. 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) Insullation 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) Insullation 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 21. Orbiter Post-Landing Microchemical Sample Results

9.0 POST LAUNCH ANOMALIES

Based on the debris inspections and film/video review, ten Post Launch Anomalies, but no IFA candidates, were observed on the STS-52 mission.

9.1 LAUNCH PAD/FACILITY

1. The GH2 vent arm retracted and latched properly. However, excessive slack was present in the static retract lanyard causing it to contact one of the carrier plate legs.

9.2 EXTERNAL TANK

1. A 5-inch divot to substrate was present in the LH2 tank acreage at XT-1399 adjacent to a previously sanded area.

2. Some of the left bipod jack pad TPS closeout was missing.

3. Foam was missing from the aft outboard corner of the left bipod ramp closeout.

4. At least 20 small pieces of TPS were missing from intertank stringers forward of the LH2 tank-to-intertank flange/bipod area. No metal substrate/primer was visible.

9.3 SOLID ROCKET BOOSTERS

1. The RH frustum had 18 MSA-2 debonds over fasteners and was missing a 1.5-inch diameter area of TPS in the -Y+Z quadrant at the 336 ring frame. The LH frustum had 27 MSA-2 debonds over fasteners and two MSA-2 acreage debonds.

2. Two MSA-2 acreage debonds were present on the RH SRB forward skirt.

3. EPON shim was missing from the HDP #3 and #8 aft skirt feet prior to water impact. The substrate was charred/sooted.

9.4 ORBITER

1. An 8"x6"x0.5" tile damage site was present on the base heat shield adjacent to SSME #1 (at approximately the 7:00 o'clock position). This damage site appeared to have been caused by a dense, rigid object and may have been caused by the lost tile.

2. A tile gap filler (V070-395052-175) from the LH aft fuselage sidewall was found on the runway after landing.

Appendix A. JSC Photographic Analysis Summary

December 17, 1992

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-52 Final Report, and was completed December 16, 1992. Publication numbers are LESC-30549 and JSC-25994-52. The actual document can be obtained through the LESC library/333-6594 or Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

Christine L. Dailey 12/17/92
Christine Dailey, Supervisor
Image Analysis Section

2.0 Summary of Significant Events Analysis

2.1 Debris

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 Ice Debris Strikes at the Orbiter/ET Umbilical Area

(Cameras E-31, OTV-109, OTV-163)

Cameras E-31 and OTV-109 showed multiple pieces of ice debris striking the LH2 umbilical electrical cable tray just after SSME ignition. Ice was also seen to strike the lower edge of the umbilical well door during this time frame. No visible damage to the SLV was apparent at either location. These events were reported to the Mission Evaluation Room (MER).

2.1.1.2 LH2 and LO2 Umbilical Disconnect Debris

(Cameras E-1, E-5, E-6, E-16, E-17, E-18, E-19, E-25, E-26, E-31, E-34, E-40, E-52, E-57, E-79, OTV-109, OTV-150, OTV-163, OTV-171)

The usual amount of ice debris from the LO2 and LH2 TSM T-0 umbilicals as well as the ET/Orbiter umbilicals were noted on many of the MLP camera films and videos. Multiple pieces of ice and/or liquid were also seen falling from the flange of the LH2 17 inch line at liftoff. No follow up action was expected.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 Square-shaped Debris falls near LH2 TSM Area

(Cameras E-18, E-76, E-77)

A small light-colored piece of debris was seen falling below the LH2 TSM T-0 disconnect on the E-18 film. (See Figure 2.1.2.1). A small orange-colored piece of debris was also seen falling by the vertical stabilizer on views from both Cameras E-76 and E-77. Analysis indicated that this was the same object first seen on the E-18 film.

KSC has positively identified this debris as a yellow GSE teflon shim. This shim is used for protecting the orbiter TPS in localized areas when adhesive is applied to the T-0 interface plate peripheral seal. Film from Cameras E-34, E-35, E-36 and E-40 (all of which showed the LH2 TSM area during the launch sequence) had been re-screened in an earlier effort to identify possible sources of the debris. None were found.

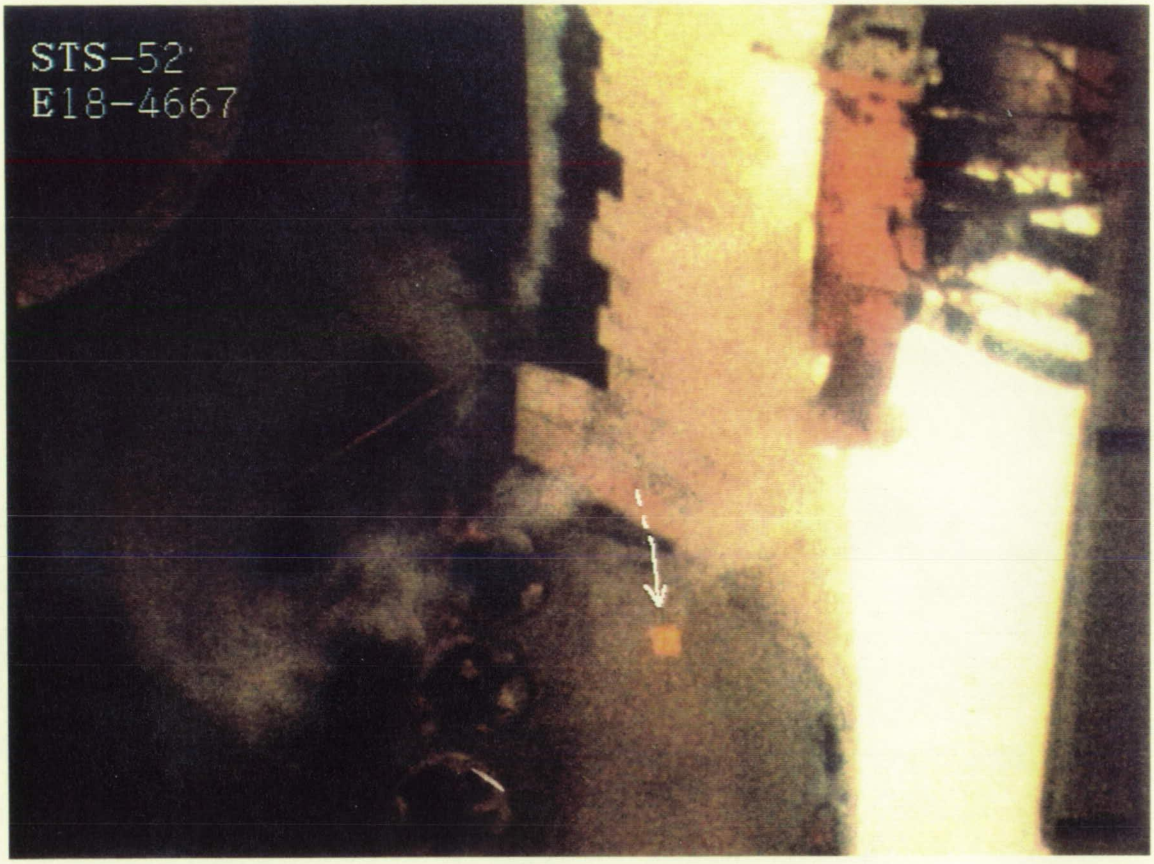


Figure 2.1.2.1 Square-shaped Debris falls from the LH2 TSM Area at Liftoff

The object seen on the E-18 film measured 2 inches square and was light in color on both sides (although one side appeared darker than the other). A trajectory plot was not constructed because of the unknown effects of airflow patterns in the region of interest. However, KSC later reported that the object was a teflon shim that had been left on the pad. The film from Camera E-18 was reviewed with a lead engineer from the JSC Thermal Subsystem Section/ES32. No further image analysis has been requested.

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

(Cameras E-3, E-7, E-8, E-9, E-10, E-11, E-12, E-13, E-14, E-15, E-16, E-25)

Multiple pieces of debris were seen coming from the SRB flame duct at the time of liftoff. These objects were not seen traveling toward the orbiter nor were they considered to be fast-moving. This event has been seen on previous missions and no follow-up analysis is anticipated.

2.1.2.3 Ice Debris at GH2 Vent Arm Retraction

(Camera E-33)

Ice was seen on the GH2 vent arm carrier plate disconnect. Multiple pieces of white debris (probably ice) were seen to fall from the GH2 vent arm during retraction. None of the ice debris appeared to strike the vehicle. No further analysis is expected.

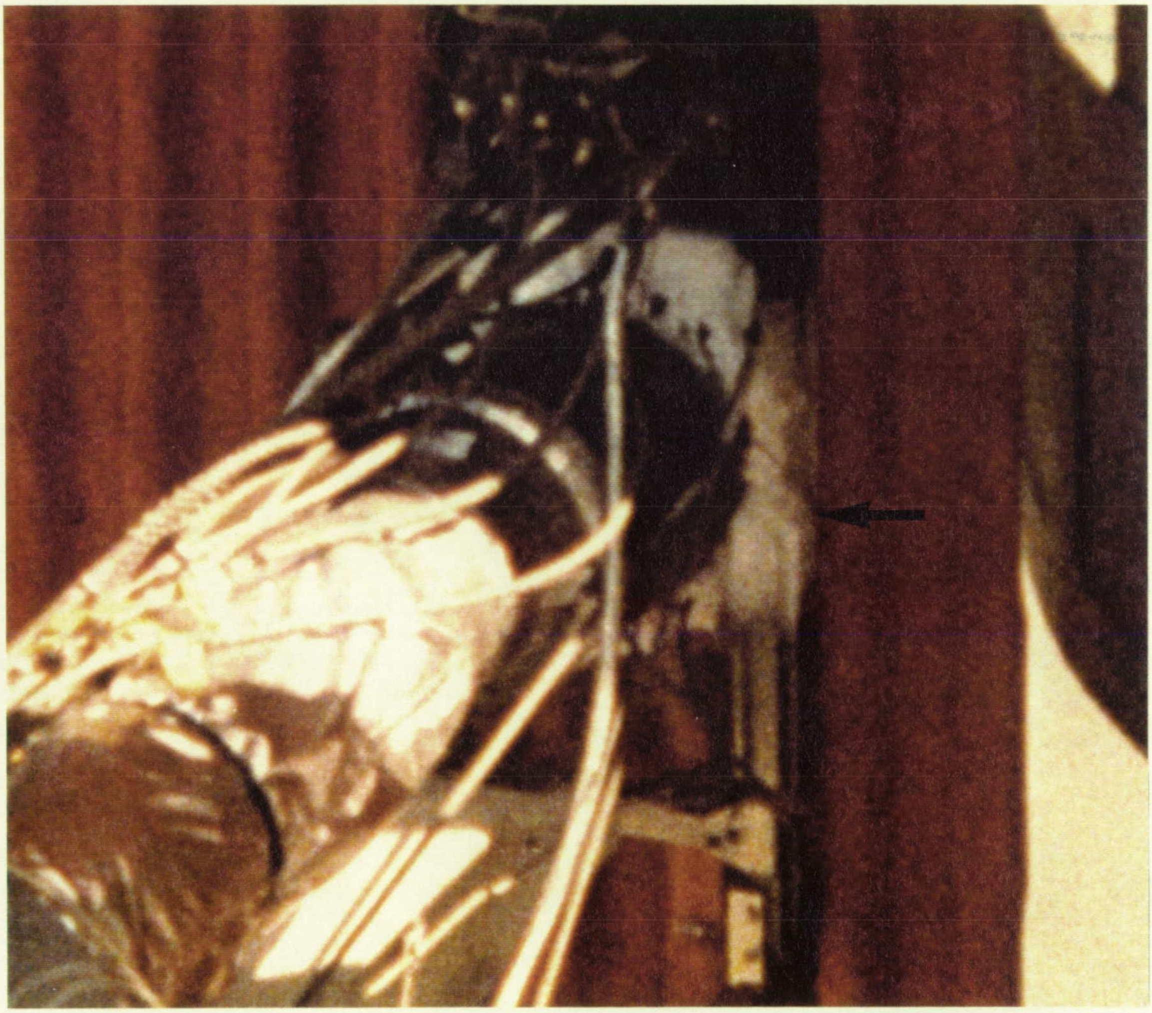


Figure 2.1.2.3 Ice Noted on GH2 Vent Arm Carrier Plate

Ice/frost was noted on and around the umbilical carrier plate prior to the launch sequence. KSC reported that the amount of ice was not excessive.

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. Debris falling aft of the SLV after liftoff has been seen on films and videos from all previous missions. Most of this type of debris has been attributed to ice from the ET/Orbiter umbilicals or RCS paper. None of the debris seen after liftoff appeared to strike the vehicle.

2.1.3.1 SLV Debris from Tower Clear through Roll Maneuver

(Cameras E-52, E-54, E-57)

Several pieces of light-colored debris (probably ice) were seen falling from the ET/Orbiter umbilical area into the SSME exhaust plume just after tower clear on Cameras E-52, E-54 and E-57. On views from Cameras E-52 and E-54, red debris (probably RCS paper from the forward thrusters) fell along both sides of the orbiter into the SSME plume during the roll maneuver.

2.1.3.2 Red Debris near SSME Exhaust Plume at 21 seconds MET

(Cameras E-212, E-213, E-220, E-222, E-223)

Cameras E-212, E-213, E-220, E-222 and E-223 showed several pieces of red debris (possibly baggy material from the ET/Orbiter umbilicals) falling aft into the SSME exhaust plume between 20.9 and 21.3 seconds MET. Similar events have been seen on previous mission films. No further analysis is expected.

2.1.3.3 White Debris seen beneath Left Inboard Elevon at 22 seconds MET

(Cameras E-54, KTV-4B)

A large piece of white debris was first noted below the left inboard elevon at 296:17:10:01.436 UTC on Camera KTV-4B. This same piece of debris was also seen falling aft of the left OMS pod at 296:17:10:01.499 UTC on Camera E-54. The debris did not appear to strike the vehicle. The origin of the object could not be identified from either view.

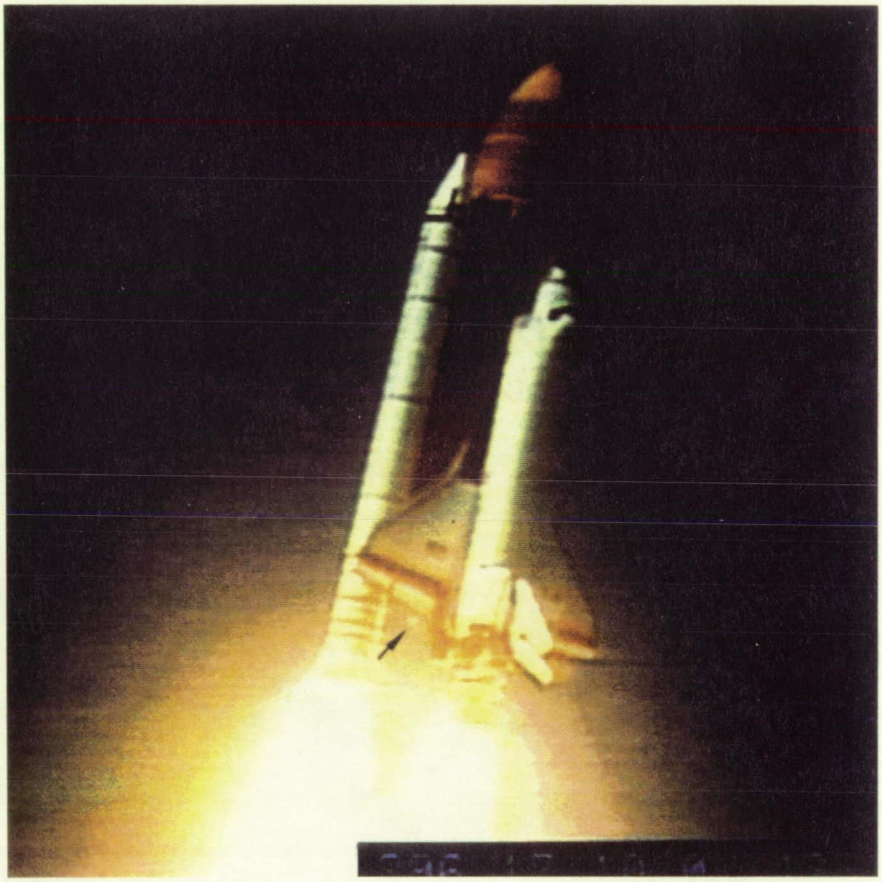


Figure 2.1.3.3 Large Piece of White Debris seen below Left Inboard Elevon after Roll Maneuver

A large piece of white debris was seen below the left inboard elevon traveling from left to right in the field-of-view at about 22 seconds MET. A source could not be determined from the available views. The object did not appear to strike the vehicle.

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. A small piece of light-colored debris was also noted falling aft along the left side of the LSRB plume at 296:17:10:20.118 UTC on film from Camera E-222. A large piece of white debris was seen aft of SSME #1 at 296:17:10:46.118 UTC on both KTV-13 and ET-208. None of this debris was seen to strike the SLV.

2.2 MLP Events

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen)

(Task #13)
(Cameras E-2, E-3, E-19, E-20, E-76, E-77)

Orange vapor (possibly free-burning hydrogen) was noted beneath SSME #1 ~1.87 seconds prior to SSME #1 ignition (formation of mach diamond). (See Figure 2.2.1). Since free burning hydrogen is essentially colorless, engineers who reviewed films after the STS-38 mission believed that the orange cloud occurred due to impurities in the vapor. Similar events have been seen on twelve of the past nineteen missions. A comparison of this event with occurrences from earlier missions was performed. The amount and position of the vapor appeared similar to that seen on STS-35. See Appendix D Task #13 for analysis details.

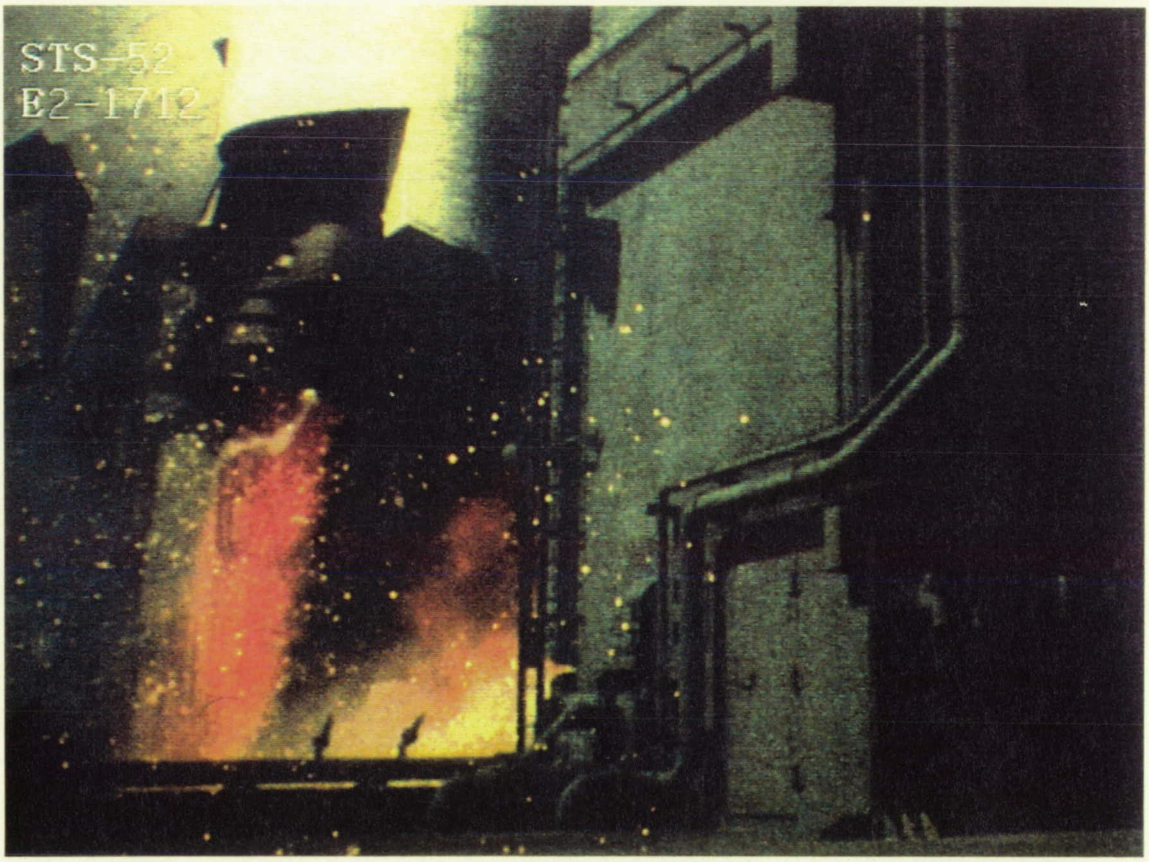


Figure 2.2.1 Orange Vapor (Possibly Free-Burning Hydrogen) Noted under the SSME #1 Bell just prior to SSME Ignition

This view from the E-2 film shows both a column of orange vapor beneath SSME #1 as well as a cloud beneath SSME #2. On some earlier missions, the orange vapor has been seen rising above the SSME bells.

2.2.2 Flashes in SSME Plumes after SSME Ignition
(Cameras E-2, E-3, E-4, E-5, E-62)

At least three orange/white flashes were noted in the SSME #1 and #2 plumes after ignition while the orbiter was still on the pad. The flashes in SSME #1 were timed at 296:17:09:36.356 UTC (T-2.658 seconds) and 296:17:09:39.252 UTC (T+0.238 seconds) as seen on Camera E-2. The flash in SSME #2 was timed at 296:17:09:37.128 UTC (T-1.886 seconds) on the same film. (See Figure 2.2.2). Flashes in the SSME plumes just after SSME ignition have been noted on ten of the past sixteen missions. While this event has not been considered anomalous in the past, future missions will be monitored for unusual occurrences or excessive numbers of flashes.

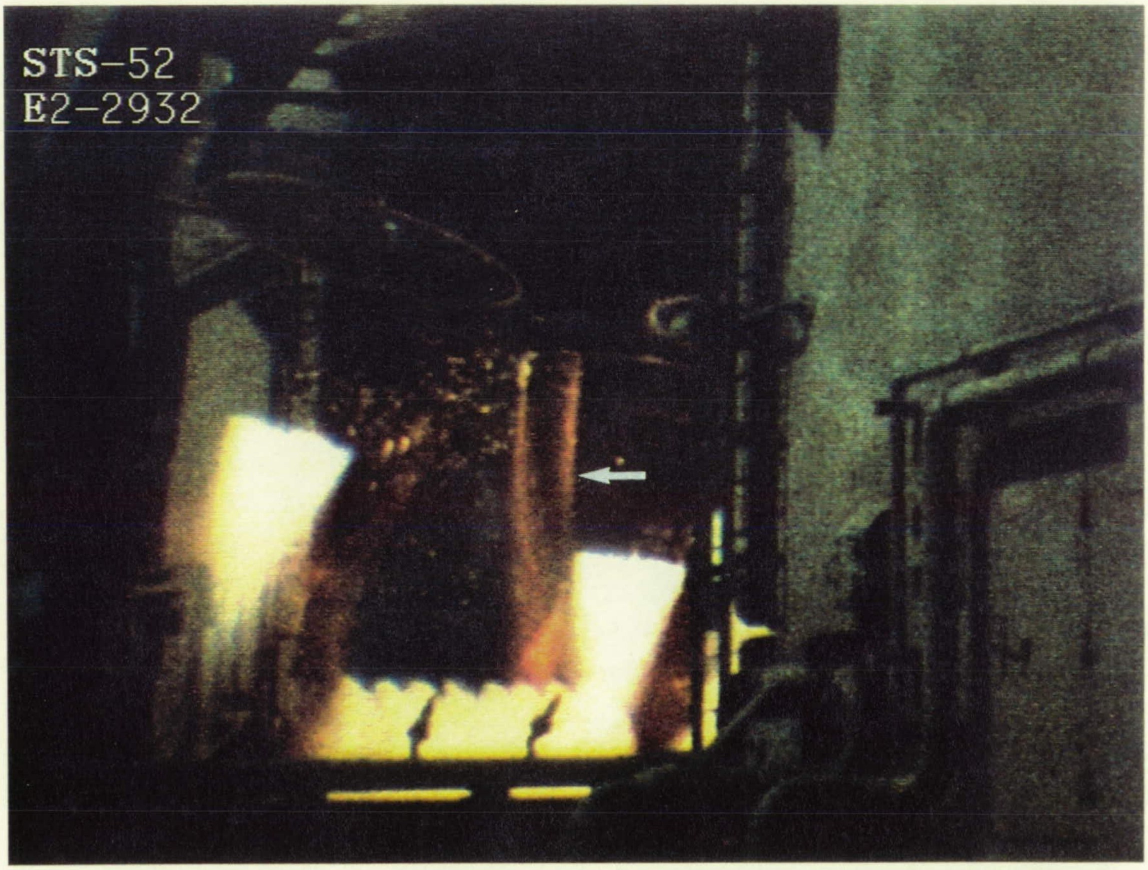


Figure 2.2.2 Flash in SSME #2 Plume 2 Seconds before Liftoff

An orange flash in the SSME #2 plume was visible at 296:17:09:37.128 UTC.

2.2.3 Base Heat Shield Erosion

(Cameras E-17, E-18, E-19)

At least six occurrences of TPS erosion were noted at the base of SSME #2 and #3. (See Figure 2.2.3). Minor TPS erosion has been seen on nearly all previous missions. The erosion visible on this mission does not appear to be related to the tile damage noted at landing (see Section 2.5.2). No follow up action is expected.

Figure 2.2.3 TPS Erosion noted on Base Heat Shield

At least three chips are visible near the base of SSME #3 on this view of the aft end of the orbiter. This occurrence is believed to result from the vibrations caused by SSME ignition.

2.3 Ascent Events

2.3.1 Loose Thermal Curtain Tape on both SRBs

(Cameras E-2, E-3, E-5, E-7, E-13, E-25, E-31, E-52, ET-212)

Loose tape was seen on both the LSRB and RSRB thermal curtains after liftoff. (See Figure 2.3.3). This event has now been seen on four missions since reflight. No further analysis is planned.

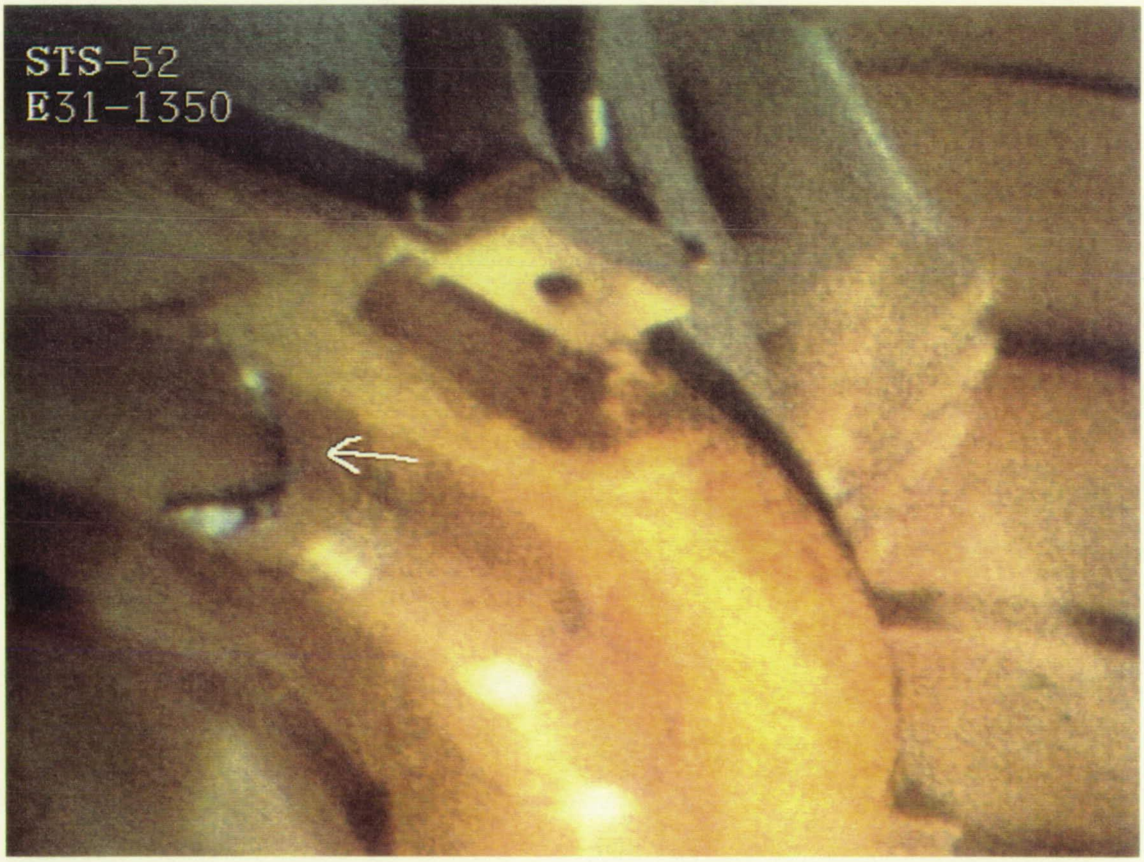


Figure 2.3.1 Loose Tape on LSRB Thermal Curtain

A loose tape was visible on the LSRB as the aft end of the SLV passed through the field-of-view during the early stages of ascent. Another piece of loose tape was seen on the RSRB thermal curtain in a different film.

2.3.2 Orange Tint in SSME Plume after Roll Maneuver
(Task # 12)
(Cameras E-208, E-222)

An orange tint was noted in the SSME plume starting at 296:17:10:07.203 UTC (28.189 seconds MET). This may have been due to unusual lighting conditions. KSC stated that this effect resulted from a normal interaction of the SSME and SRB exhaust plumes.

A study of the five previous missions (STS-29, STS-37, STS-43, STS-46 and STS-50) launched at approximately the same time of day and at the same inclination angle as STS-52 was conducted. Only the E-208 film from STS-29 showed the appearance of an orange tint in the SSME plume. See Appendix D Task #12 for analysis details.

2.3.3 Flares in SSME Exhaust Plume
(Cameras E-54, E-207, E-208, E-212, E-213, E-218, E-222, E-223, ET-212, KTV-4B)

At least seven orange-colored flares were noted in the SSME plumes from about 17 seconds MET to 34 seconds MET on Camera E-218. Flares during this time period have been seen on several earlier missions. Flares on earlier missions have been attributed to RCS paper burning up in the plume. No follow up action is expected.

2.3.4 Body Flap Motion *(Task #4)*
(Cameras E-207, E-220)

Slight body flap motion was seen at around 38 seconds MET on Cameras E-207 and E-220. Small amounts of body flap and elevon motion were also noted at the time of SSME and SRB ignition. Body flap, vertical stabilizer and wing motion have all been seen on previous mission films. The magnitude of motion seen on the views was not sufficient to warrant further analysis. Documentation can be found in Appendix D, Task #4.

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

A single linear optical distortion was noted during ascent at 296:17:10:30.803 UTC on several tracking cameras. Linear optical effects have been seen on fifteen of the past sixteen missions. In the past, JSC engineers have attributed this event to shock waves distorting the refractive index of the atmosphere during ascent. No follow up action has been requested.

2.3.6 Bright puffs near SRB plume
(Camera ET-207)

Bright objects were seen near the left edge of the SRB plume aft of the vehicle on Camera ET-207 at 296:17:10:50.202 UTC. This effect was possibly due to mixing of the SRB and SSME plumes. No further analysis is expected.

2.3.7 Recirculation *(Task #1)*
(Cameras ET-204, ET-208, ET-212, KTV-13, E-204, E-205, E-208, E-212)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all previous missions. For STS-52, the start of recirculation was observed at about 92 seconds MET and the end was noted at approximately 113 seconds MET on Camera E-208. See Appendix D Task #1 for a summary of recirculation start and stop times for all missions since reflight.

<u>Cameras on which recirculation was observed for STS-52</u>

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-204	-	-
ET-208	92	111
ET-212	-	-
KTV-13	92	112
E-204	-	-
E-205	-	-
E-208	92	113
E-212	frame 5400	frame 6500

* BEST VIEW OF RECIRCULATION

NOTE: **Intermittent LOV due to the SRB and SSME plumes prevented acquisition of specific start and stop times for recirculation on camera ET-204, ET-212, E-204 and E-205.**

2.3.8 Dark Puffs in SRB Plume before SRB Separation
(Cameras E-205, E-207, ET-207)

At least six dark puffs were noted in the SRB exhaust plume just prior to SRB separation (around 112 seconds MET). Similar events have been noted on STS-34, STS-39 and STS-47. No follow up action is expected.

2.4 DTO-0312 Analysis

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

2.4.1.1 16 mm Views of SRB Separation
(Magazines 68 - 5 mm lens and 69 - 10 mm lens)

Separation of the LSRB from the external tank appeared normal on the 16 mm umbilical well film views No anomalies were observed on the LSRB surface areas. Multiple divots and chipped areas were visible on the base of the electric cable tray. A nearly square-shaped piece of light colored debris was noted approximately 3 seconds prior to the SRB separation. A dark, irregularly-shaped piece of debris was seen to come from behind the electric cable tray at approximately 2.4 seconds prior to the separation. A smear appeared in the upper left corner of the field-of-view at approximately 0.88 seconds prior to separation (5 mm camera film). The aft ET/Orbiter attach brace and the ET aft dome show charring similar to that seen on previous mission umbilical films.

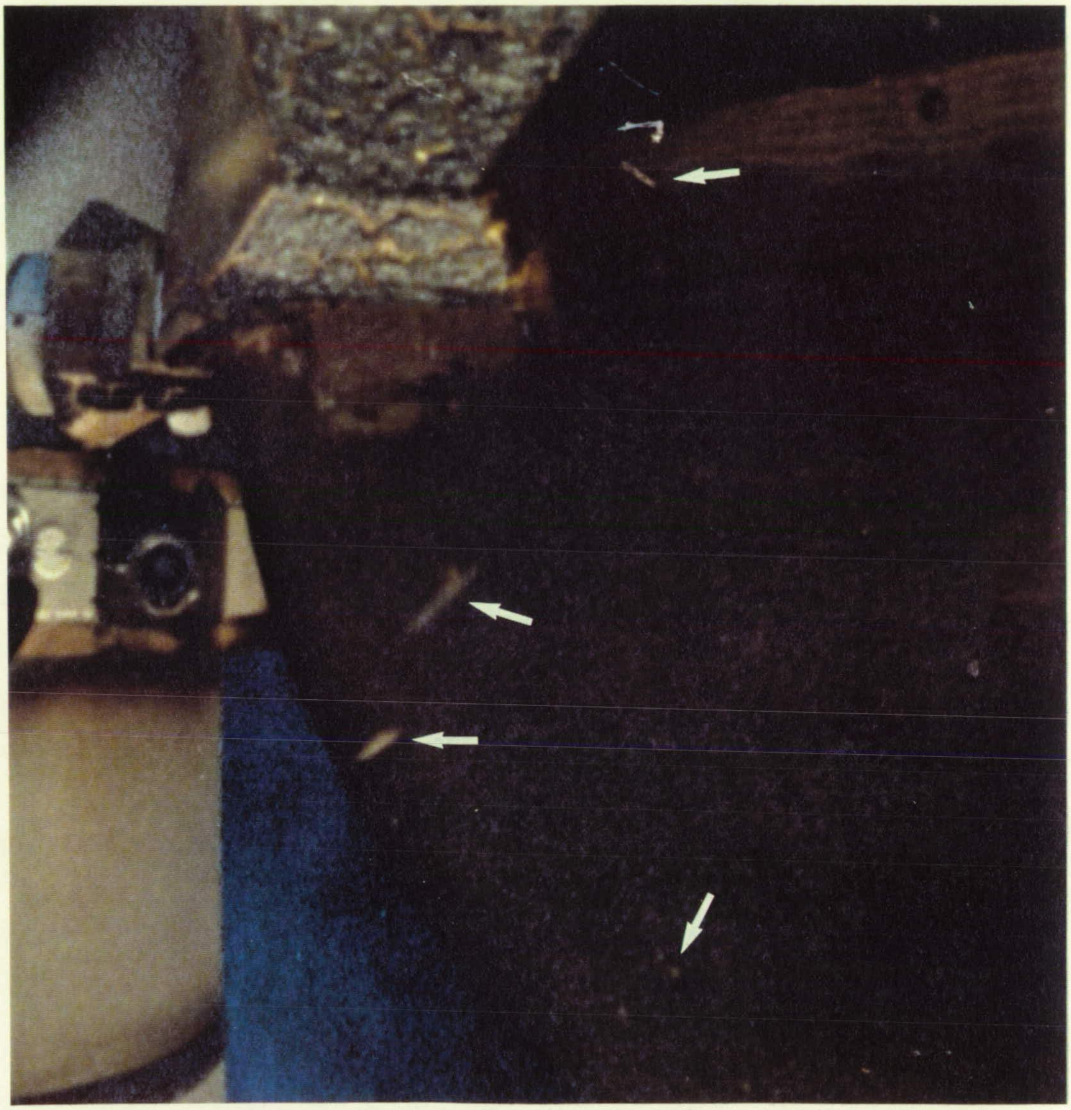


Figure 2.4.1.1 16 mm View (10 mm Lens) of LSRB Separation

Numerous pieces of small debris were seen in the 16 mm umbilical camera film views 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.

2.4.1.2 16 mm Views of ET Separation
(Magazines 68 - 5 mm lens and 69 - 10 mm lens)

The ET/Orbiter umbilicals appeared normal during 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 films. Two dark, fast-moving pieces of debris were seen in the umbilical purge vapors prior to ET separation.

The events seen in the separation sequence of the external tank are similar to the events seen on the previous mission umbilical well camera films.

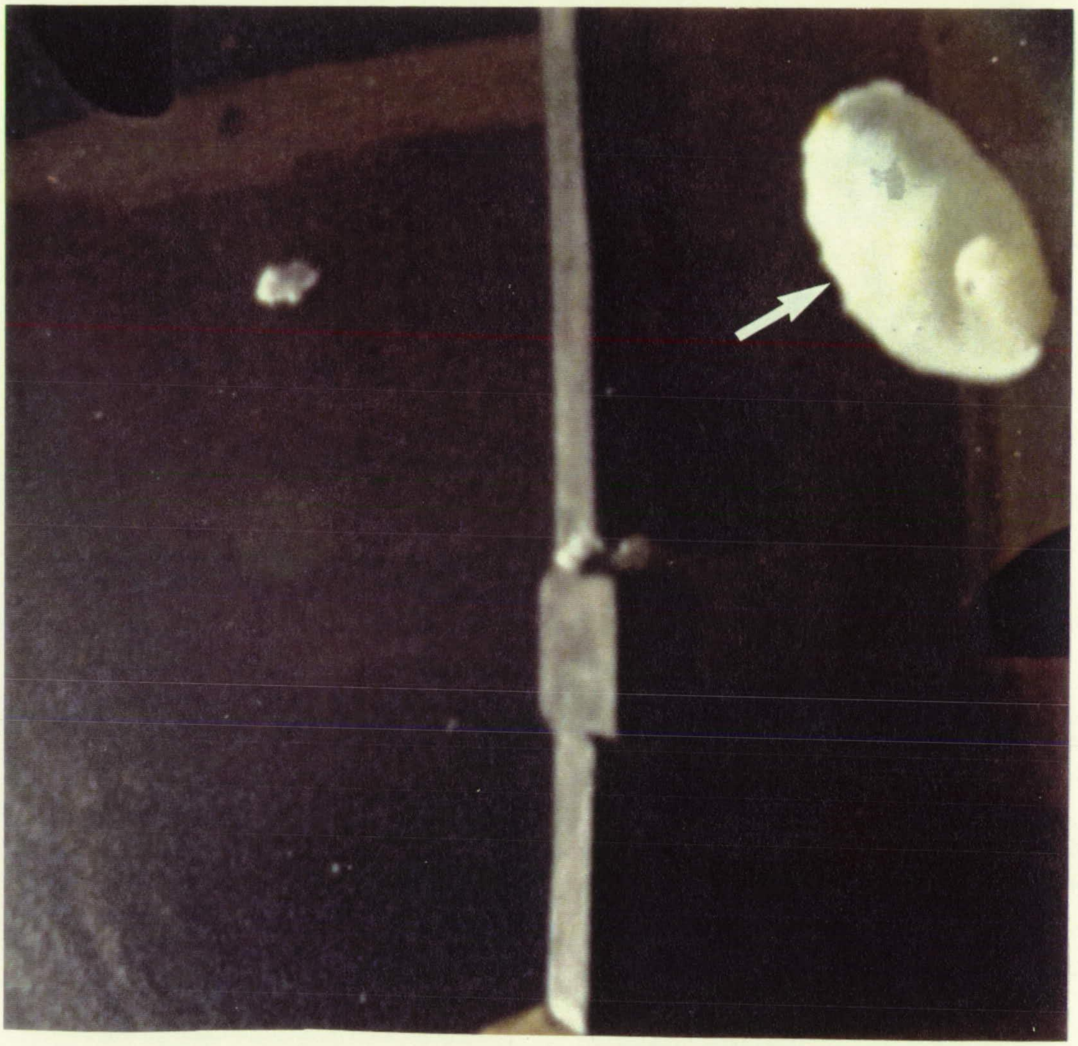


Figure 2.4.1.2 (A) Ice from Forward Purge Vent Tube Visible at ET Separation

A single, large, white cylindrical-shaped piece of debris was seen to travel across the FOV just before ET separation. KSC reported that this debris was an ice finger from a forward purge vent tube.

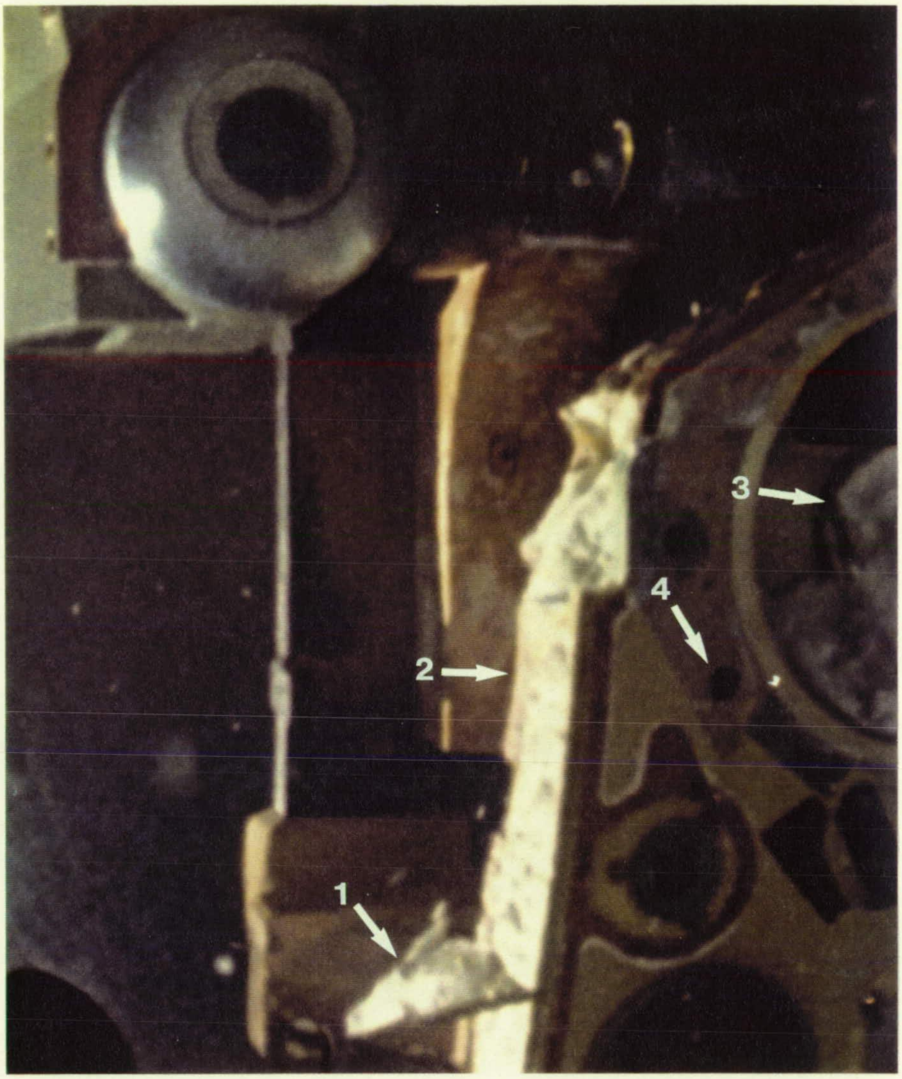


Figure 2.4.1.2 (B) LH2 ET Umbilical at ET Separation

A small piece of foam like material moved across the ET LH2 umbilical just after ET separation (1). 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 (2). Ice was visible in the orifice of the LH2 17 inch line as the LH2 umbilical came into full view (3). The bushing sleeves appeared to be present in their proper positions (4). (The cylindrical-shaped debris object seen on the STS-40 umbilical well film was believed to have been a dislodged bushing sleeve).

2.4.1.3 35 mm Umbilical Well Camera Views of the ET Separation

The external tank nose cone, LO2 acreage PAL ramps and the ET aft dome acreage appeared normal on the 35 mm umbilical well camera views. The SRB BSM burn scars on the O-give were typical of previous mission views. Small white marks or chipping of the TPS on the ramp over the electric cable tray and pressurization line just above the LO2 umbilical were visible. Small white marks on the tank TPS were also visible to the right (in the FOV) of the LO2 umbilical and on the forward end of the ET/Orbiter aft attach strut.

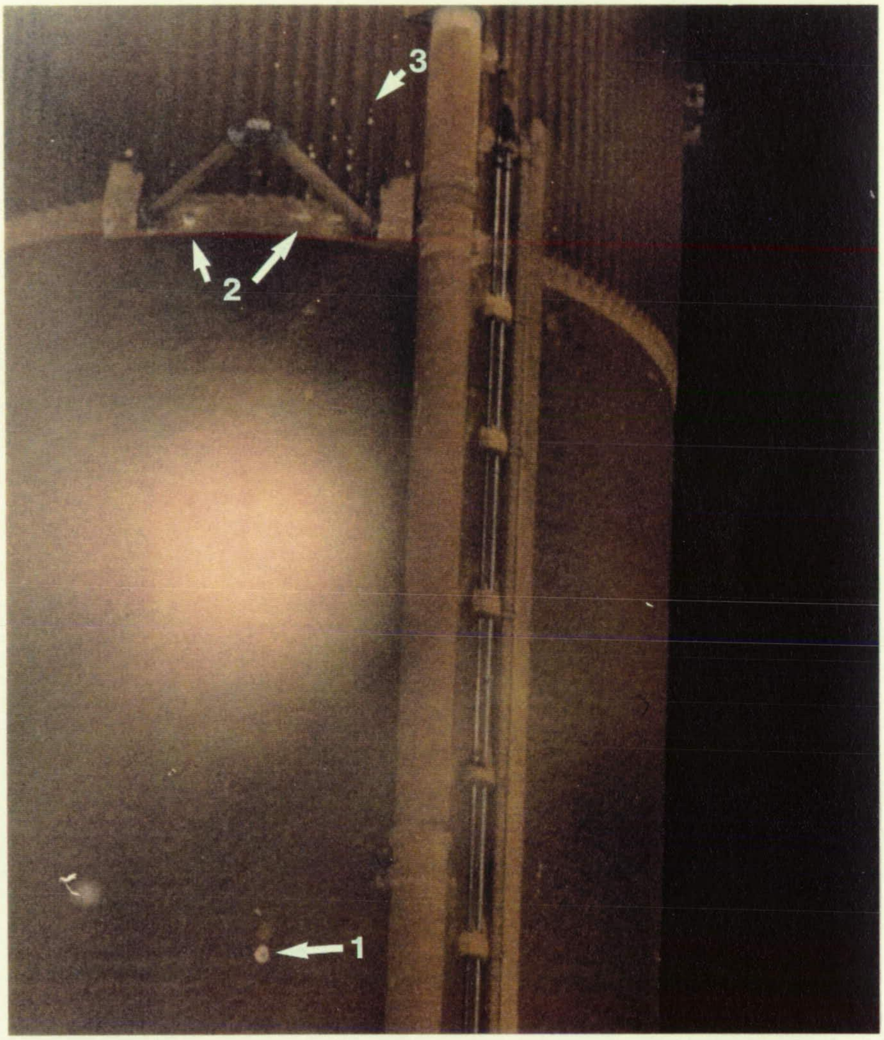


Figure 2.4.1.3 Small White Marks/Divots seen on ET +y TPS

A divot was seen on the LH2 tank TPS approximately ten feet below the intertank closeout line (+Z axis to the left of the LO2 feedline). The divot was estimated to be approximately six inches in size (1).

Small white marks were visible under the ET/Orbiter forward attach bipod (one possible small divot) in the area of the left bipod jack pad and ramp TPS closeout (2). Small white "popcorn" marks were seen on the intertank TPS above the forward bipod (3). The larger divots that have been seen near the forward ET/Orbiter attach bipod, along the intertank close-out, and on the intertank TPS on previous mission films were not visible on the STS-52 tank. (A large divot under the forward bipod was declared an inflight anomaly on STS-47).

Detailed analysis on the umbilical well films can be found in Appendix D Task #5.

2.4.2 Onboard Handheld Camera ET Analysis *(Task #6)* *(Photographs 52-42-01 thru 52-42-36)*

DTO-0312 Method 3 was performed aboard STS-52. This method incorporates use of a 300 mm lens on a Nikon F4 camera body. The photographs were taken between 17:27:35 (approximately 10 minutes after ET separation) and 17:33:40 UTC by astronaut Lacy Veech. At the time of the first photograph, the ET was approximately 2.52 km from the orbiter. The photographs were screened shortly after landing. The photographs were generally too dark to perform a detailed analysis. Each frame was well focused and contained GMT time. The photographs were backlit, which means that the available light was not reflecting from the ET but rather was directly in the camera's field-of-view.

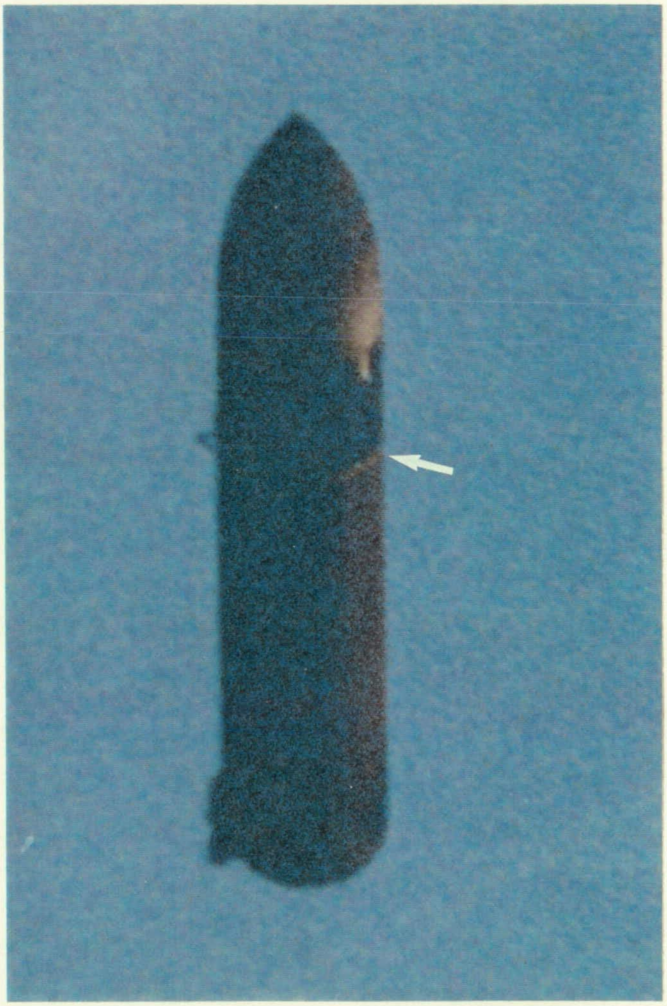


Figure 2.4.2 Possible Divots on the LH2/Intertank Interface

The detailed screening revealed two possible divots in the LH2 intertank interface on the +Y axis. The ET tumbled at approximately 0.124 revolutions per minute about a plane which intersected the optic axis. Updates to the DTO-0312 have been incorporated into the next mission's procedures that should increase the quality of the photography.

Detailed notes for all the photographic screening are located in Appendix D Task #6.

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 distance between the left and right inboard tires was used to scale the measurements. Data was gathered from approximately one second prior to landing through touchdown. A point on both the top of the left and right inboard main landing gear wheels was digitized for 100 frames. This raw data was corrected for the vertical change in scale at each frame. The vertical distance between the top of the wheel in the first frame and each subsequent frame 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 1.7 ft/sec. which is well within the current threshold limits.

Nose gear touchdown occurred approximately 18 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 approximately one second prior to nose gear touchdown. Three points on every other frame over a period of 148 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 2.6 ft/sec. which is also well within the current threshold limits.

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

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

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 1.1 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 Damaged Base Heat Shield Tile Between SSMEs #2 and #3 *(Task #14)*

A large portion of tile V070-395093-016 was missing from the base heat shield between SSMEs #2 and #3. (See Figure 2.5.2). According to KSC, the tile suffered an in-plane failure leaving the strain isolation pad and densified tile material in the cavity. An In Flight Anomaly (IFA) has been declared to document this discrepancy.

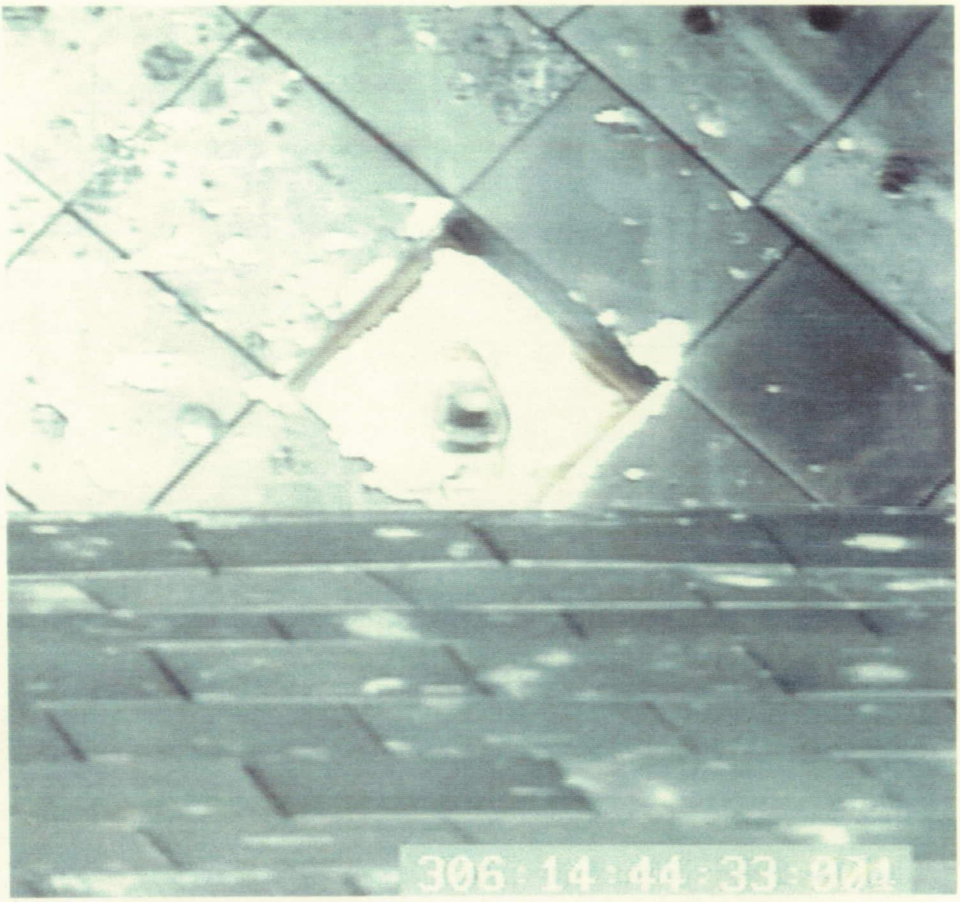


Figure 2.5.2 **Damage to Base Heat Shield Tile seen during Post Landing Inspection**

A large portion of this base heat shield tile (V070-395093-016) between SSMEs #2 and #3 appears to be missing. This picture, taken during the post-flight inspection, shows the exposed calorimeter and some of the residual tile material still in the cavity.

Launch films were reviewed to determine whether or not the tile in question was visible during the launch and ascent phases of the mission. The majority of evidence indicated that the tile was still present through tower clear. Beyond that time frame, film resolution of the area in question made further analysis inconclusive. See Appendix D Task #14 for details.

In addition to the missing tile, damage was present on the base heat shield adjacent to SSME #1 (near the 7:00 o'clock position). According to KSC, this damage may have been caused by the lost tile.

2.5.3 Drag Chute Performance

(Task #9)
(Cameras EL-07, EL-07a, EL-010, EL-09, EL-09a, EL-12, EL-15)

The landing of Columbia at the end of mission STS-52 marked the fourth deployment of the Orbiter drag chute. The drag chute initiated 13.763 seconds after main gear touchdown. While in the reefed configuration, the chute stayed near the vehicle centerline near a heading angle of -1 degree and a riser angle of 7 degrees; however, after disreefing, the drag chute move to the vehicle's left side. The heading angle oscillated, having a minimum of -10 degrees before eventually returning to a maximum of 3 degrees. The riser angle had a minimum of -8 degrees and a maximum of 1 degree during this time interval. The maximum drag chute deflection along the vehicle's y-axis was approximately 15 feet (4.6 meters). The drag chute was released 44.205 seconds after touchdown. At drag chute release, the heading angle was approximately -4 degrees and the riser angle was approximately -5 degrees. All heading and riser angle measurements are relative to the Orbiter's x-axis.

An attempt to measure the deceleration of the vehicle between full inflation reefed configuration to chute release from visual data indicated an average deceleration of 3.2 feet/sec^2 (0.98 meters/sec^2). The velocity of the vehicle was found to range from approximately 282 feet/sec (86.0 meters/sec) to approximately 79 feet/sec (24 meters/sec) over the near 29 second time interval of data taken.

Graphical representation of the data described may be found in Appendix D, Task 9.

2.6 Other Normal Events

Other events seen on the STS-52 launch views that have been seen on previous shuttle flights include: smoke from the hydrogen ignitors during startup; RCS paper in the 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; 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
AC(205)544-2121

NASA

Reply to Attn of: EP53 (92-112)

TO: Distribution

FROM: EP53/Tom Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-52

Enclosed is the Engineering Photographic Analysis Report for the Space Shuttle Mission STS-52. For additional copies, or for further information concerning this report, contact Tom Rieckhoff at 544-7677, or Darlene Busing, Rockwell at 971-3174.

Tom Rieckhoff

Enclosure

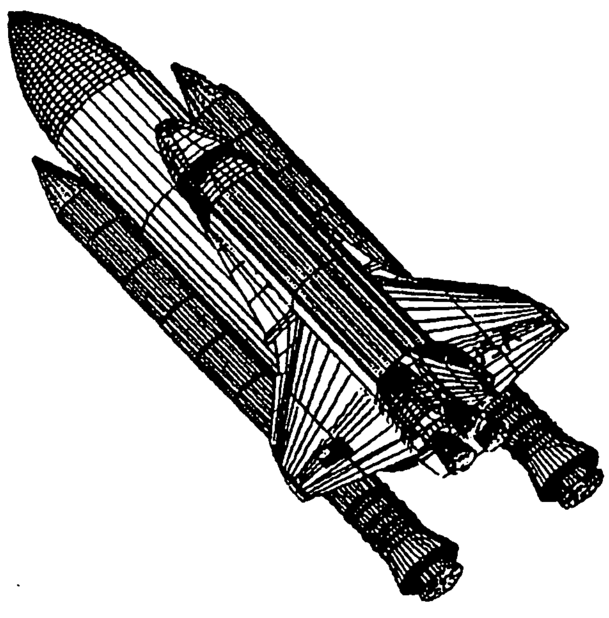
National Aeronautics and
Space Administration

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

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-52



MSFC - Form 454 (Rev. October 1976)

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-52

FINAL

PREPARED BY:

D.BUSING, J. HIXSON, B. VIGER
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JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

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B. LINDLEY-ANDERSON, MSFC/EP53

STS-52 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

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

November 18, 1992

I. INTRODUCTION

Space Shuttle Mission STS-52, the thirteenth flight of the Orbiter Columbia was conducted October 22, 1992 at approximately 12:09 P.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-52 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-six of fifty-seven requested cameras as well as video from twenty-four of twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-52.

CAMERA DATA RECEIVED FOR STS-52

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	2	3	6
Tracking	0	16	11
Onboard	4	2	0
Totals	35	21	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-52 was considered good. Coverage from some tracking cameras was limited due to cloud coverage. Camera E-65 jammed while starting providing no data. Camera E-218 malfunctioned, providing a short run, with no loss of data. Camera E-54 was shipped as E-59 and E-59 shipped as E-54. Some of the video cameras also experienced distorted video signals during launch.

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 35mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. Two 16mm motion picture cameras and one 35mm still camera were flown on this mission in the Orbiter's umbilical well to record the SRB and ET separation 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. Loose Thermal Curtain Tape:

Figures one and two are frames of film from cameras E-5 and E-13 respectively. These figures show one piece of loose thermal curtain tape on the right SRB (camera E-5) and one piece on the left SRB (camera E-13).

c. T-0 Umbilical Debris:

Figure three is a frame of film from camera E-18 showing a piece of debris which fell from the LH2 T-0 umbilical as it retracted from the vehicle. The debris object was square in shape and light colored. It is estimated that the object is about 2 inches in size. This debris was identified, post flight, as a yellow GSE teflon shim.

d. Pad Debris Striking SRB:

Figure four is a film frame showing a piece of pad debris from the SRB blast hole which strikes the base of the left SRB systems tunnel. There was no apparent damage to the vehicle.

e. ET TPS Divots:

Figure five is a film frame showing one divot noted near the center of the LH2 tank near the LOX line. Figure six is a film frame showing several small divots noted on the right side of the bipod on the intertank. These divots were recorded on the 35mm still camera located in the Orbiter's LO2 umbilical well.

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	296:17:09:39.017
M-2	E-8	296:17:09:39.017
M-5	E-12	296:17:09:39.016
M-6	E-13	296:17:09:39.017

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 30.3 inches. Figure five 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-52 was determined to be 296:17:11:42.17 UTC taken from camera E-207.

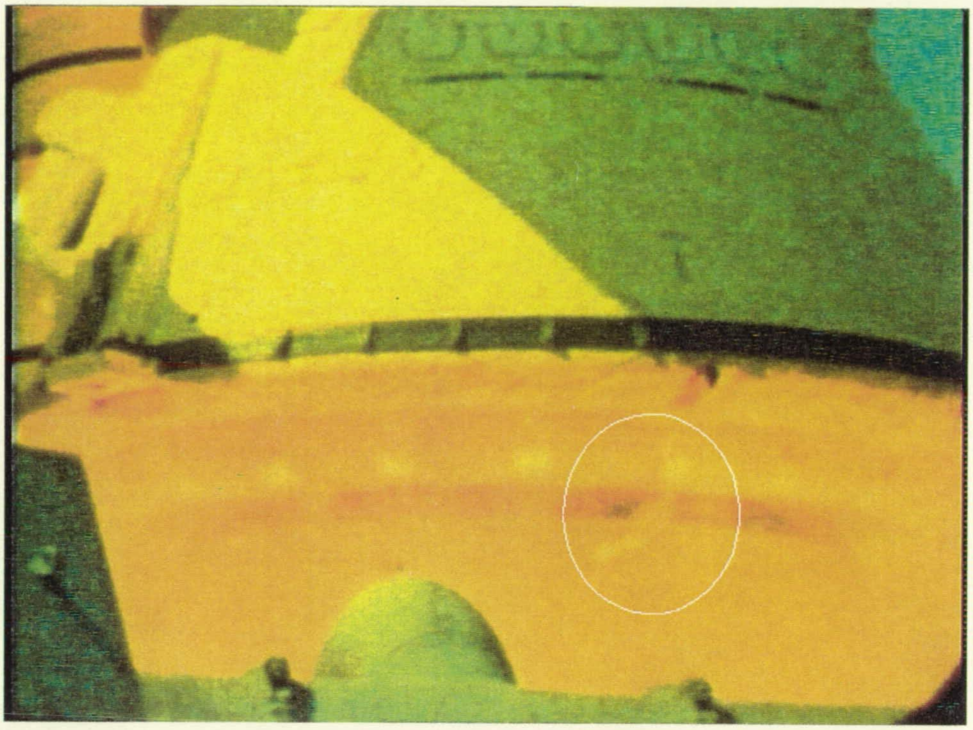

Figure 1

Loose Thermal Curtain Tape

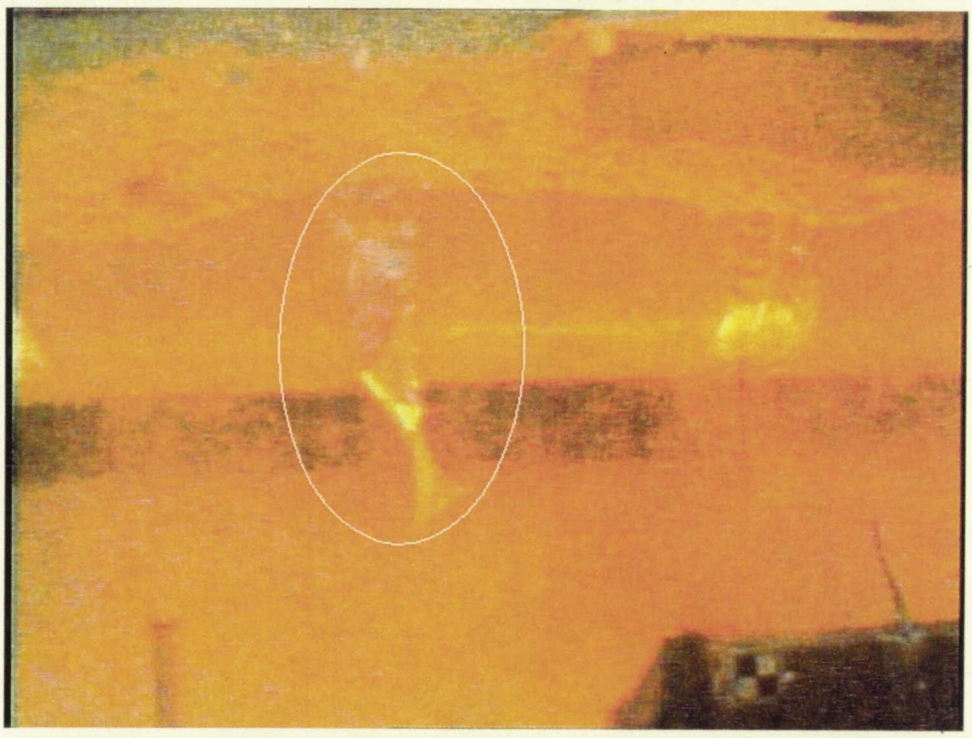

Figure 2

Loose Thermal Curtain Tape

Figure 3

Debris Noted From LH2 T-0 Umbilical

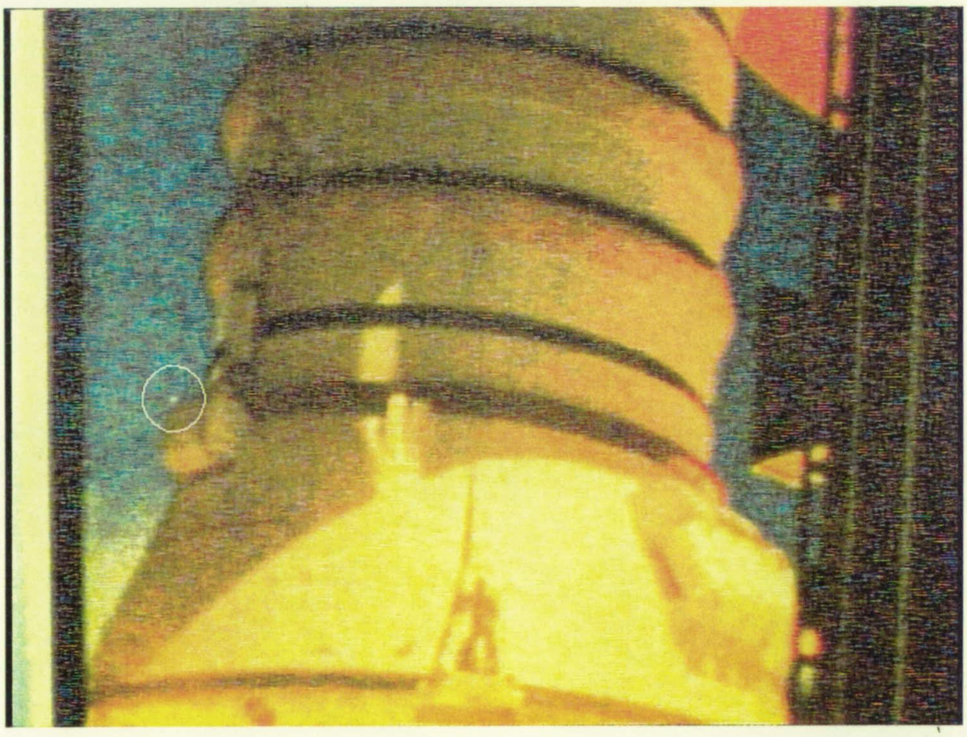

Figure 4

Pad Debris Noted From SRB Blast Hole

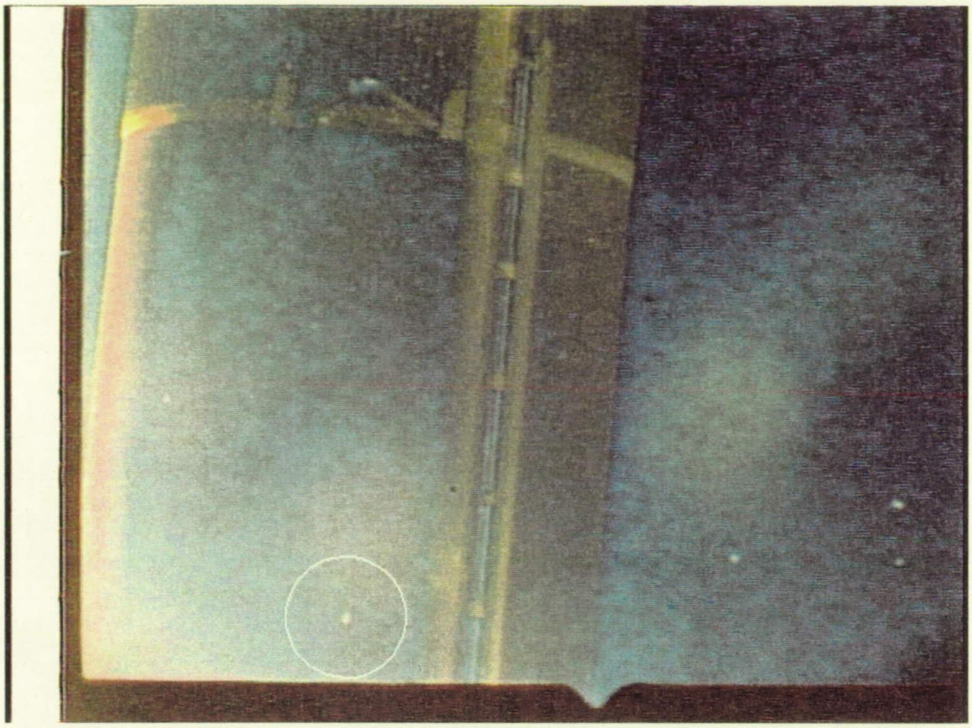

Figure 5

Divot Noted Towards Center of the LH2 Tank Near the LOX Line

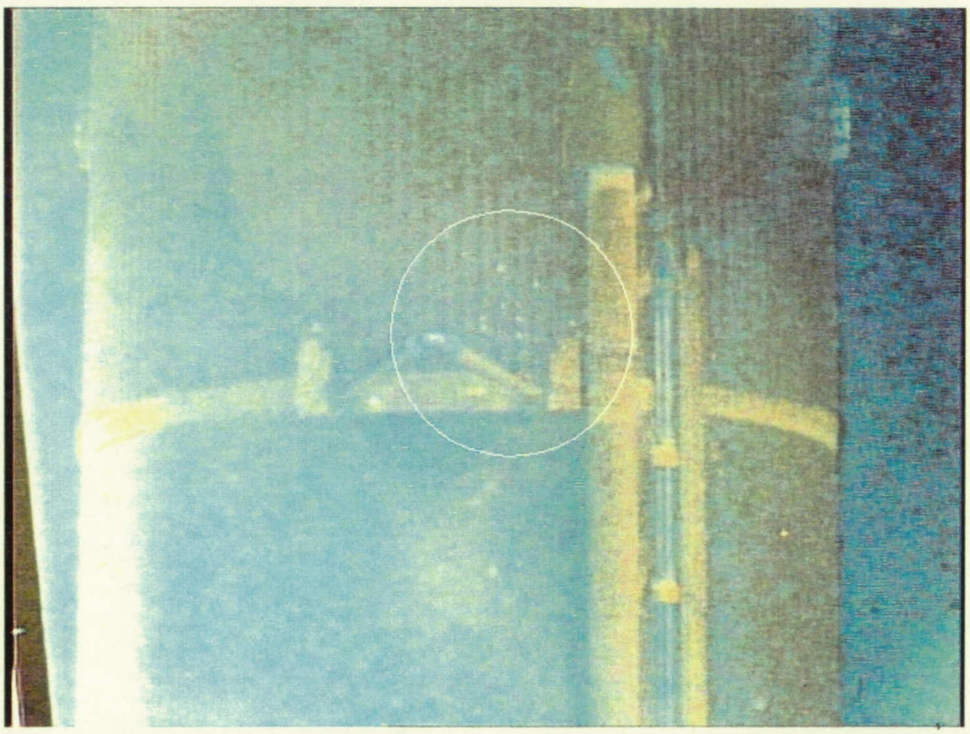

Figure 6

Several Small Divots Noted on Right Side of the Bipod on the Intertank

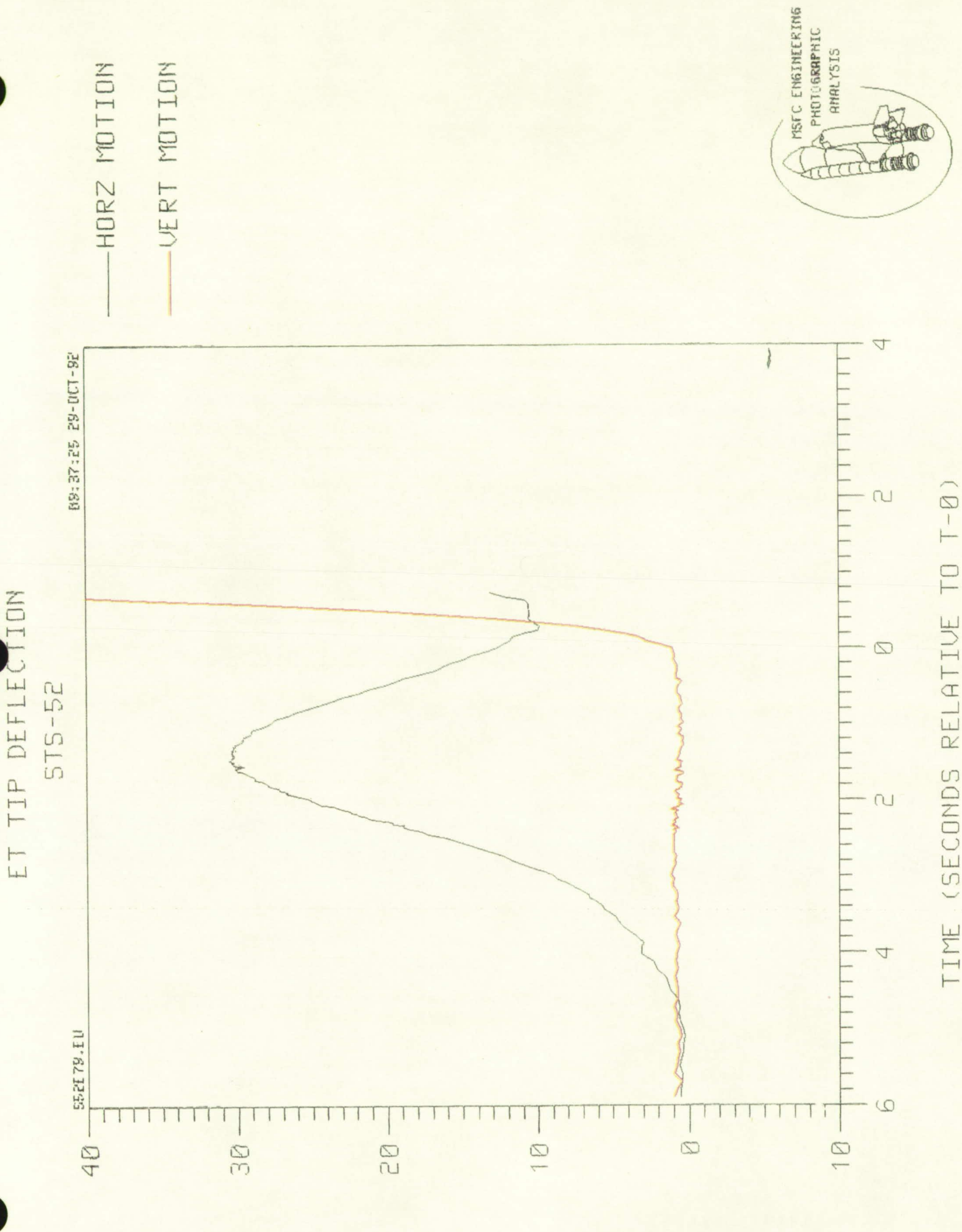

Figure 7

ORIGINAL PAGE
COLOR PHOTOGRAPH

Appendix C. Rockwell Photographic Analysis Summary

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

Rockwell International

December 4, 1992

In Reply Refer to 92MA5217

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-52 Mission.

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

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39B Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-52 launch conducted on October 22, 1992, at approximately 10:09 AM (PDT) from the Kennedy Space Center (KSC) and for the landing on November 1, 1992 at KSC (6:05 AM PST).

Rockwell received launch films from 81 cameras (59 cine, 22 video) and landing films from 22 cameras (16 cine, 6 video) to support the STS-52 photographic evaluation effort.

All ground camera coverage for this mission including coverage on the MLP, FSS and tracking cameras were good.

Overall, the films showed STS-52 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 and brightening of the SRB plumes were visible and normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal.

(Packing Sheet No. DM92-22214)

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-52 was the eleventh flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up. No material was observed originating from the DCS area during liftoff.

No major or significant events were observed or identified. One item that merits mentioning (not considered an anomaly) is the small square shaped object seen near the left side of the orbiter near the TSM disconnect area by MSFC. This event and other events noted by the Rockwell film/users during the review and analysis of the STS-52 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. On camera E-18, E-76 and E-77, MSFC reported seeing a small square shaped object beneath the LH2 TSM T-O disconnect on the E-18 film. Review of the E-18 film by JSC and Rockwell verified the presence of this object. The object was light in color on both sides and estimated to be approximately two inches square. However, the debris object is not believed to be a tile because of the thin appearance in the edge views. The debris object could possibly be a shim, a tag, or a spacer.

   A small orange-colored piece of debris was observed on cameras E-76 and E-77 which appeared to originate from the LH2 TSM umbilical area. Review of the films by JSC, MSFC, KSC and Rockwell concluded that this is the same debris that was seen on camera E-18. No further analysis is planned.

2. Orange vapor (possibly free burning hydrogen) was seen beneath SSME #1 just prior to SSME ignition on cameras E-2, E-3, E-19, E-20, E-76 and E-77. 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.

3. White flashes were seen in the SSME #1 and #2 plumes after after SSME ignition and prior to liftoff (cameras E-2, E-3, E-4, E-5, and E-62). Orange/white flashes have been observed on previous missions. No follow-up action is planned.

4. On cameras OTV-109, OTV-154, OTV-163 and OTV-164, multiple pieces of white debris (probably ice) was seen falling from the ET/Orbiter umbilicals at SSME ignition. Several of these particles contacted the LH2 umbilical cable tray, aft sill of the umbilical cavity and may have contacted the

underside of the orbiter at liftoff, but no damage to the tiles was detected. No follow-up action is planned.

5. Numerous pieces of flight-colored debris seen coming from the SRB flame ducts at SRB ignition and liftoff (cameras E-1, E-2, E-3, E-7, E-14, E-15 and E-25). None of the debris appeared to strike the vehicle. No follow-up action is planned..

6. On cameras OTV-154, E-2, E-3, E-5, E-7, E-13, E-25, E-31, E-34 and E-52, a piece of loose tape was noted on the right SRB and left SRB thermal curtains after liftoff. Loose thermal curtain tape has been on previous missions. No follow-up action is planned.

7. Flexing (fore and aft motion) was noted, in the base heat shield in the centerline area, between the SSME cluster during the early stage of SSME ignition (cameras E-76 and E-77). The motion was similar to that observed on previous launches. No follow-up action is required.

8. Flares and flashes seen in the SSME exhaust plume (ET-212, E-52, E-54, E-207, E-212, E-213, and E-222) at approximately 17.5 seconds MET and between 30 and 34 seconds MET. These observations have been seen in the SSME exhaust plumes on previous missions and are understood to be burning of propellant impurities including RCS paper covers. No follow-up action is planned.

9. On cameras ET-207, E-205 and E-207, dark puffs were noted in the SRB plume at approximately 113 seconds MET (prior to plume brightening). Dark/orange puffs have been seen on previous missions and no follow-up action is planned.

10. The following events have been reported on previous missions and observed on STS-52. 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.
    - Debris pieces in the SSME/SRB plumes.
    - ET aft dome outgassing and charring.
    - Slight elevon motion at SSME ignition.
    - Twang motion.
    - Body flap motion during the maximum dynamic pressure (MAX-Q) region which appeared to have an amplitude and frequency similar to those of previous missions.
    - Linear optical distortion, possibly caused by shock waves or ambient meteorological conditions near the vehicle, during ascent.
    - Slag in SRB plume after separation.

11. 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.

12. 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.

13. The landing of STS-52 occurred on runway 33 at the KSC Shuttle landing facility. Good video and film coverage were obtained and no anomalous events were observed. This flight marked the fourth use of the Orbiter drag chute. The drag chute appeared to have functioned normally. During the post-landing inspection video views, a tile appeared to be missing between SSME #2 and SSME #3 on the base heat shield above the body flap. Further review indicated erosion of the surface coating and densified layer on a development flight instrumentation tile, instrumented with a calorimeter. It is not on issue and is considered normal wear and tear. No follow-up action is required.

This letter is of particular interest to W. J. Gaylor (VF2) and J. M. Stearns (WE3) at JSC. The Integration Contractor contact is R. Ramon at (310) 922-3679.

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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-52, and the resulting effect on the Space Shuttle Program.

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