Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-64

Gregory N. Katnik, Barry C. Bowen, J. Bradley Davis,
Vehicle Engineering/Mechanical System Division/ET Section,
Kennedy Space Center, Florida

Technical Memorandum 109206 October 1994

DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-64

9 August 1994

Prepared By:

J. Bradley Davis
Digital Imaging Systems
NASA/Kennedy Space Center

Barry C. Bowen
Infrared Scanning Systems
NASA/Kennedy Space Center

Jorge E. Rivera
Mechanical/Structural Systems
NASA/Kennedy Space Center

Robert F. Speece
Thermal Protection Systems
NASA/Kennedy Space Center

Approved:

Gregory N. Katnik
Shuttle Ice/Debris Systems
NASA/Kennedy Space Center
TV-MSD-7

James G. Tatum
Chief, ET/SRB Mechanical Systems
NASA/Kennedy Space Center
TV-MSD-7

TABLE OF CONTENTS

TABLE OF PHOTOS

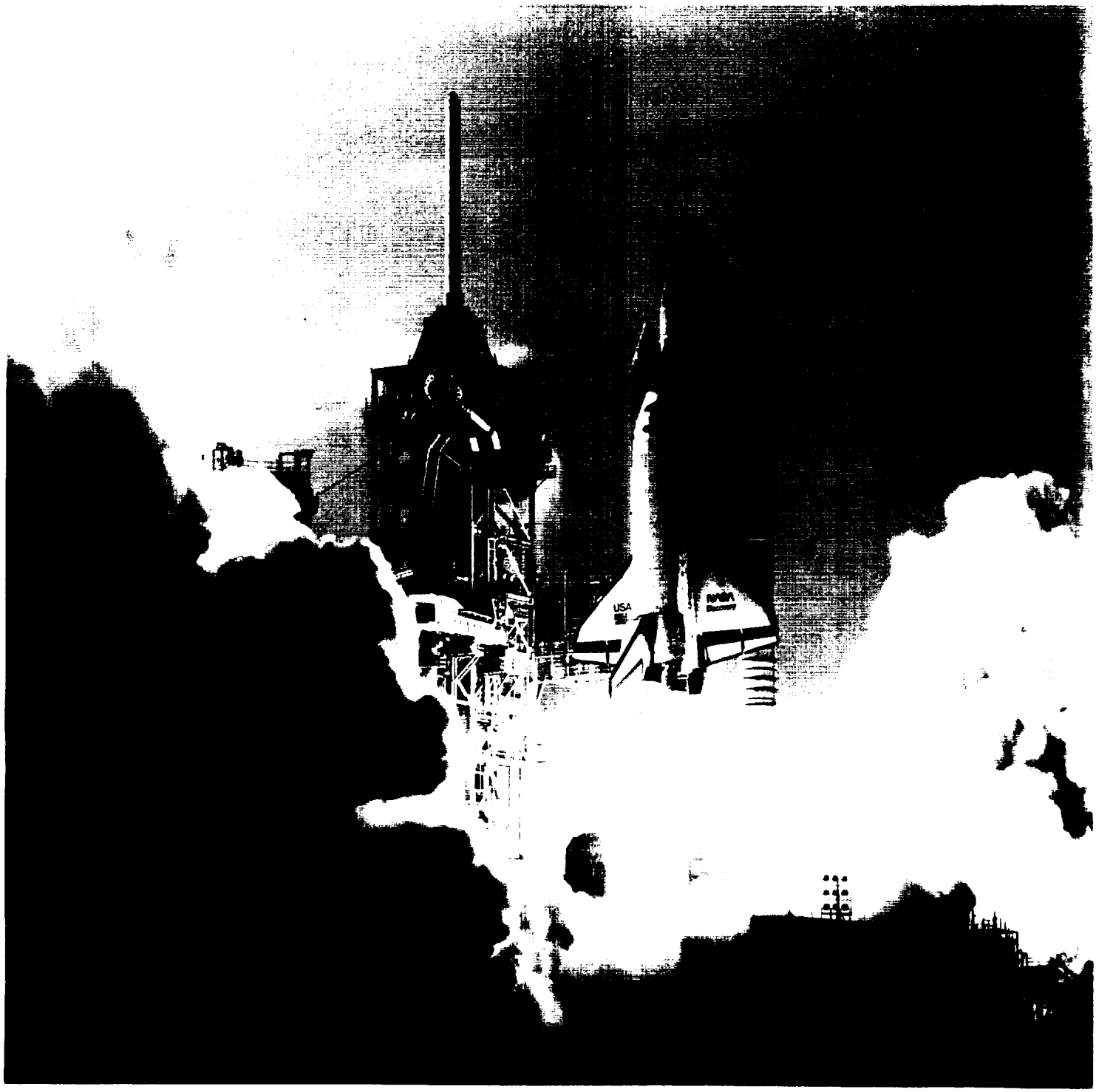


Photo 1 : Launch of Shuttle Mission STS-64

1.0 SUMMARY

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 8 September 1994. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (19th flight), ET-66 (LWT 59), and BI-068 SRB's. There were no significant facility or vehicle anomalies.

The vehicle was cryoloaded on 9 September 1994. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

After the 6:23 p.m. (local) launch on 9 September 1994, a debris walk down of Pad 39B was performed. No flight hardware or TPS materials were found. There was no visual indication of a stud hang-up on any of the south holddown posts. Overall, damage to the launch pad was minimal.

A total of 110 films and videos were analyzed as part of the post launch data review. The vehicle sustained no significant damage or lost flight hardware that would have affected the mission.

On-orbit photography revealed elevon divots, ranging in size from 6 to 10 inches in diameter, in the LH2 tank-to-intertank flange closeout +Y-Z quadrant. The divots were generally located in an area aft of the RSS antenna.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. From a debris standpoint, both SRB's were in good condition. Both frustums had a combined total of 38 MSA-2 debonds. A 2" x 1" x 1.5" cavity was present in the ETA ring forward surface TPS near the RH SRB upper strut. Crushed foam inside the cavity appeared charred and may be indicative of a debris impact early in flight. Post flight laboratory analysis revealed no embedded material, particles, or residue. The cavity/debris impact damage site was most likely caused by ice.

The LH SRB systems tunnel cover-to-aft skirt "rooster tail" interface plate was damaged by water "slap back" at splashdown.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-103 Discovery was conducted on the runway at Dryden Flight Research Center/Edwards AFB. The Orbiter TPS sustained a total of 150 hits, of which 19 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of debris hits was slightly greater than average while the number of hits 1-inch or larger was less than average. The Orbiter lower surface had a total of 116 hits, of which 18 had a major dimension of 1-inch or larger The ET/Orbiter separation devices functioned properly. No debris was found on the runway below the umbilical cavities.

An 18-inch section of main landing gear door thermal barrier, including carrier panel, was missing from the aft inboard area of both left and right gear wells (IFA STS-64-V-08: PR LWING-3-20-5466 and PR RWING-3-20-4896). These pieces (part numbers V070-199052-013 and -014) fell from the vehicle during gear deployment and were subsequently found approximately 4000 feet from the runway 04 threshold. The RH thermal barrier assembly apparently caused 5 damage sites on the tiles aft of that location. The PR's were closed by modifying the thermal barrier assembly installation procedures.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 8 September 1994 at 1530 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC	Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC	Shuttle Ice/Debris Systems
B. Davis	NASA - KSC	Digital Imaging Systems
R. Speece	NASA - KSC	Lead, Thermal Protection Sys
B. Bowen	NASA - KSC	Infrared Scanning Systems
J. Rivera	NASA - KSC	Lead, ET Mechanisms/Structures
M. Bassignani	NASA - KSC	ET Mechanisms, Structures
J. Cawby	LSOC - SPC	ET Mechanical Systems
J. Blue	LSOC - SPC	ET Processing
R. Seale	LSOC - SPC	ET Processing
J. Kercsmar	LSOC - SPC	ET Processing
G. Fales	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
M. Wollam	LSOC - SPC	ET Processing
W. Richards	LSOC - SPC	ET Processing
Z. Byrns	NASA - KSC	Level II Integration
J. Stone	RI - DNY	Aero, Debris Assess, LVL II Integ
K.Mayer	RI - LSS	Rockwell Integration
R. Haskell	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing
K. Ely	MMMSS- LSS	ET Processing
D. Maxwell	LSOC - SPC	Safety

3.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed no condensate or ice/frost accumulations on the LO2 tank. There were no TPS anomalies. The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate. There were no LH2 tank TPS acreage anomalies. No condensate or ice/frost accumulations were present on the acreage.

There were no anomalies on the bipod jack pad closeouts. A crack, 8 inches long by 3/8 inch wide, was present in the -Y ET/SRB cable tray forward surface TPS. The presence of the crack was acceptable for flight per the NSTS-08303 criteria.

Less than usual amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

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

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/ frost fingers had formed on the pyro canister and plate gap purge vents. The 17-inch flapper valve actuator access port foam plug was properly closed out. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

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

Anomaly 001 documented an 8-inch by 3/8-inch crack in the forward surface TPS of the -Y vertical strut/ET-SRB cable tray.

Anomaly 002 documented ice/frost formations on the LO2 ET/ORB umbilical purge vents and the LH2 ET/ORB umbilical purge vents, recirculation line bellows, and purge barrier.

Anomaly 003 documented ice/frost formations in the LO2 feedline support brackets and bellows.

3.6 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

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

No damage to the ET nosecone/footprint area was visible after the GOX vent hood was retracted.

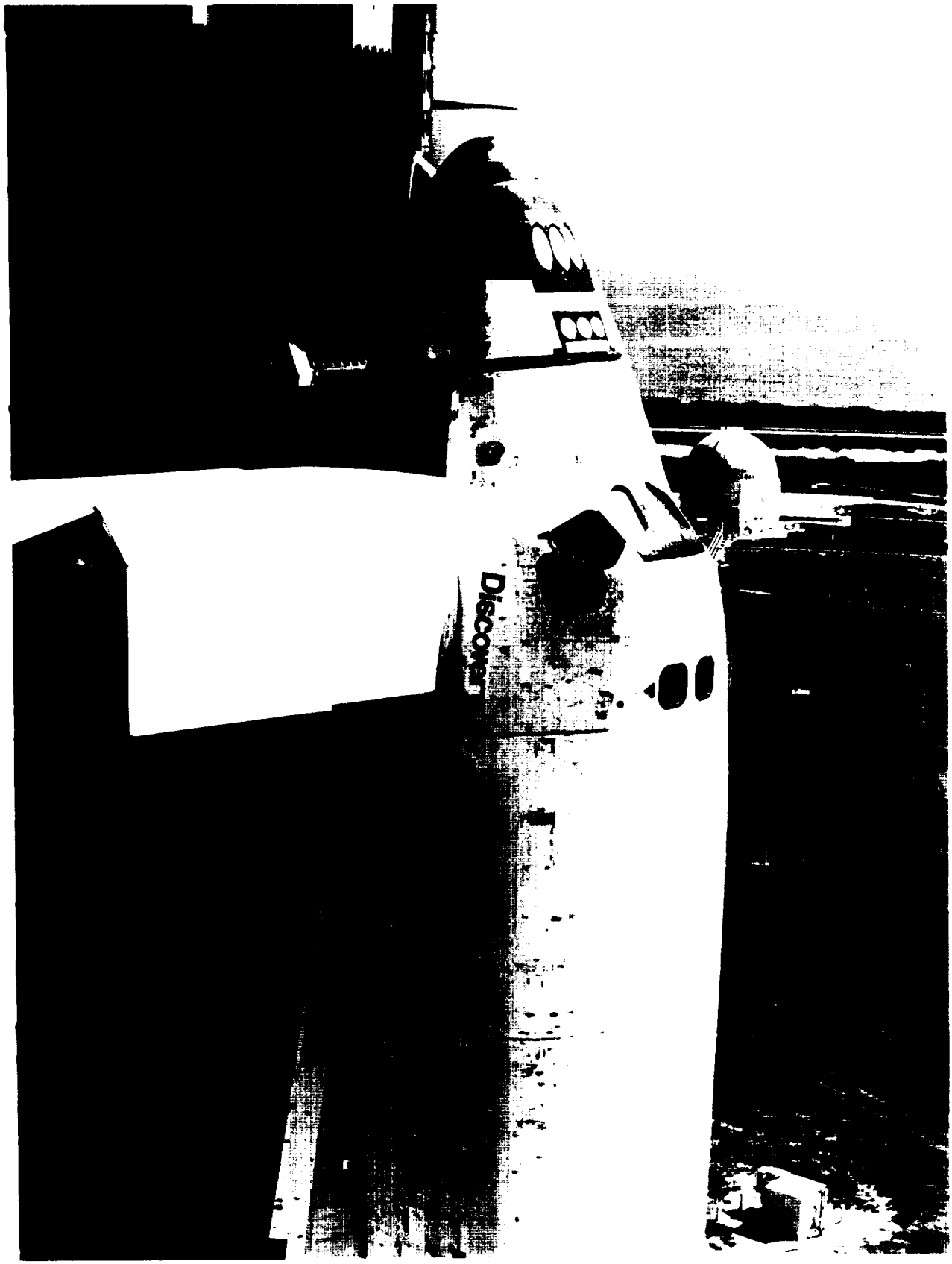


Photo 2 : Overall View of STS-64 Vehicle

OV-103 Discovery (19th flight), ET-66 (LWT 59), and BI-068 SRB's

Photo 3 : Overall view of SSME cluster

ORIGINAL PAGE
COLOR PHOTOGRAPH

Photo 4 : LH2 ET/Orbiter umbilical

Less than usual ice/frost had formed on the umbilical during cryoload

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS and RSS was conducted on 9 September 1994 from 1.5 to 3 hours after launch.

No flight hardware or TPS materials were found.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was normal and there were no burn-throughs. The SRB aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent arm appeared undamaged. An 8 inch piece of mylar tape was hanging from the upper edge of the LH2 TSM T-0 opening and was probably from the TSM purge barrier baggie.

The GH2 vent line was latched on the eighth tooth of the latching mechanism, had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound.

A bolt head was sheared from a cover plate on the MLP deck camera E-27 box mount (northeast corner of the right SRB exhaust hole). The flat and lock washers from this bolt were also missing. Cable tray covers were missing and/or loose on the 95, 115, 135 and 175 foot levels of the FSS.

A 4-foot section of handrail and an 8-foot section of cable tray cover were found on the southwest corner of the pad apron.

Debris inspections of the pad acreage, apron, and flame trenches were performed. No flight hardware or TPS material was found. Approximately three square feet of refractory concrete was missing from the main SRB flame deflector (east side). Helicopter overflight of the beach and areas outside the pad perimeter was canceled due to inclement weather.

Post launch pad inspection anomalies are listed in Section 9.

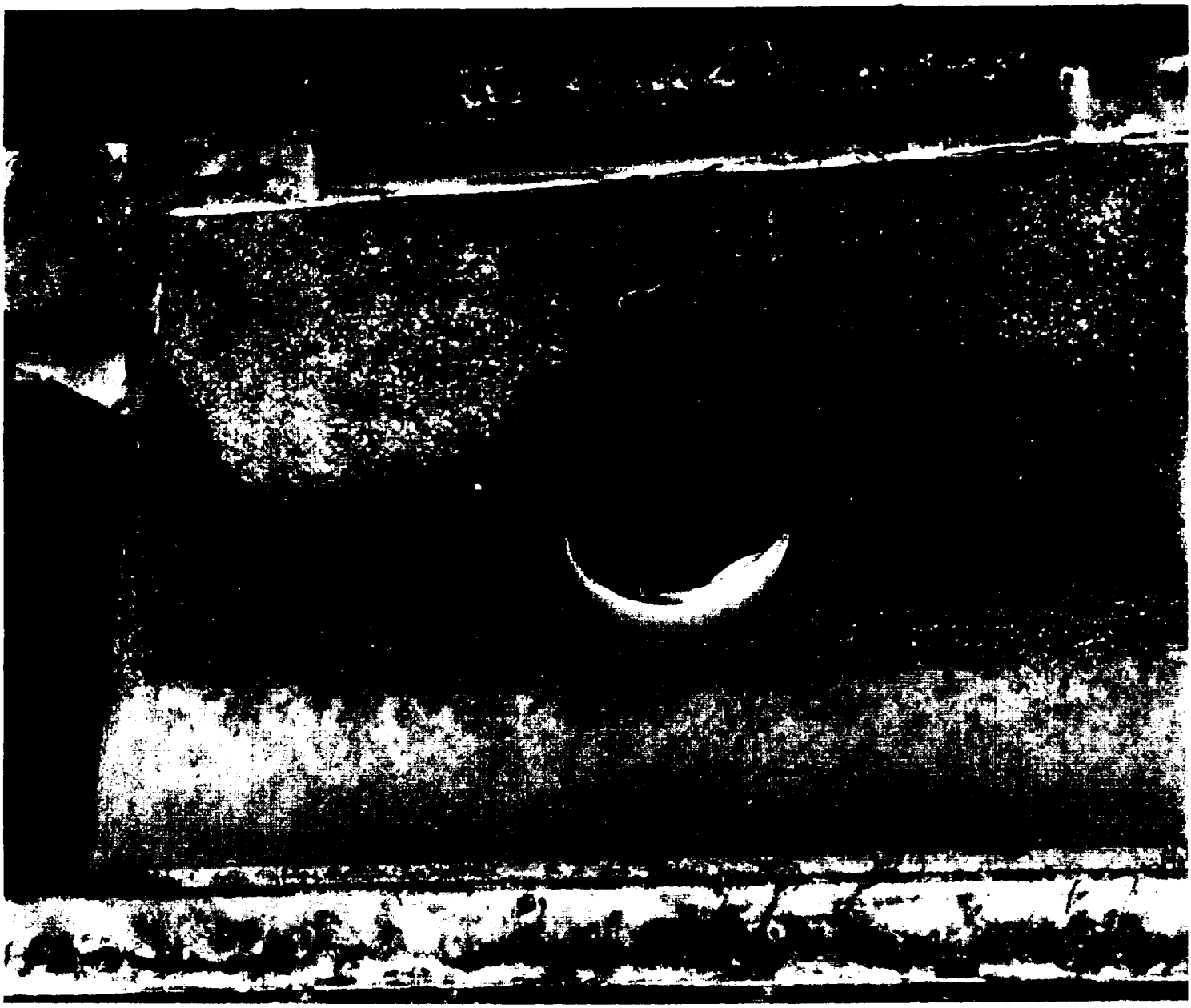


Photo 5 : Typical post launch condition of south holddown post

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or In-Flight Anomalies were generated as a result of the film review. Post flight anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 98 films and videos, which included thirty-eight 16mm films, twenty 35mm films, three 70mm films, and thirty-seven videos, were reviewed starting on launch day.

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

Residual gaseous oxygen vapors exited the louvers after the GOX vent hood was retracted. Dark residue was again visible on the ET nosecone topcoat in the footprint/grid area after the GOX vent seals were retracted (OTV 160, 162).

SSME ignition, Mach diamond formation, and gimbal profile appeared normal (OTV 151, 170, 171). Free burning hydrogen from pre-ignition drifted under the body flap and up to the LH OMS pod (OTV 163, 171). No significant amount of surface coating material was lost from base heat shield or OMS pod tiles (E-19, -20).

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. Some pieces of ice contacted the umbilical cavity sill and were deflected outward, but no tile damage was visible (OTV 109, 163). Two pieces of mylar tape, 6 inches long by 1 inch wide, fell from the LH2 ET door hinge area during ignition (OTV 109). The tape is used for ET/ORB umbilical purge barrier installation.

Ice particles from the LO2 feedline upper bellows fell outboard of the EO-3 fitting during SSME ignition. No contact with Orbiter tiles was observed (E-5, -6).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150). A small, dark, debris particle fell from the LO2 TSM door area after the T-0 carrier plate retracted, but did not contact the Orbiter (E-17).

GUCP disconnect from the ET was normal (E-33). Small ice particles, but no TPS, fell from the interface area after disconnect. The GH2 vent line appeared to latch properly with no rebound (OTV 160, E-42, -48). There was some excess slack in the static retract lanyard and a section of the cable contacted the GUCP legs during retraction. No damage resulted from the contact.

No stud hang-ups occurred on any of the holddown posts. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes. All north holddown posts doghouse blast covers closed normally.

A 2" x 1", thin, rigid object, possibly a cable part tag, appeared behind the HDP #3 shoe (E-10).

A 3" x 3" piece of aft skirt foam broke loose from an area near the HDP #6 structure shortly after liftoff (E-13).

Three pieces of ET/ORB umbilical purge barrier material fell aft (E-207, frame 1005) along with ice and RCS paper covers (frames 926 and 1487; E-59) during and after the roll maneuver (E-59).

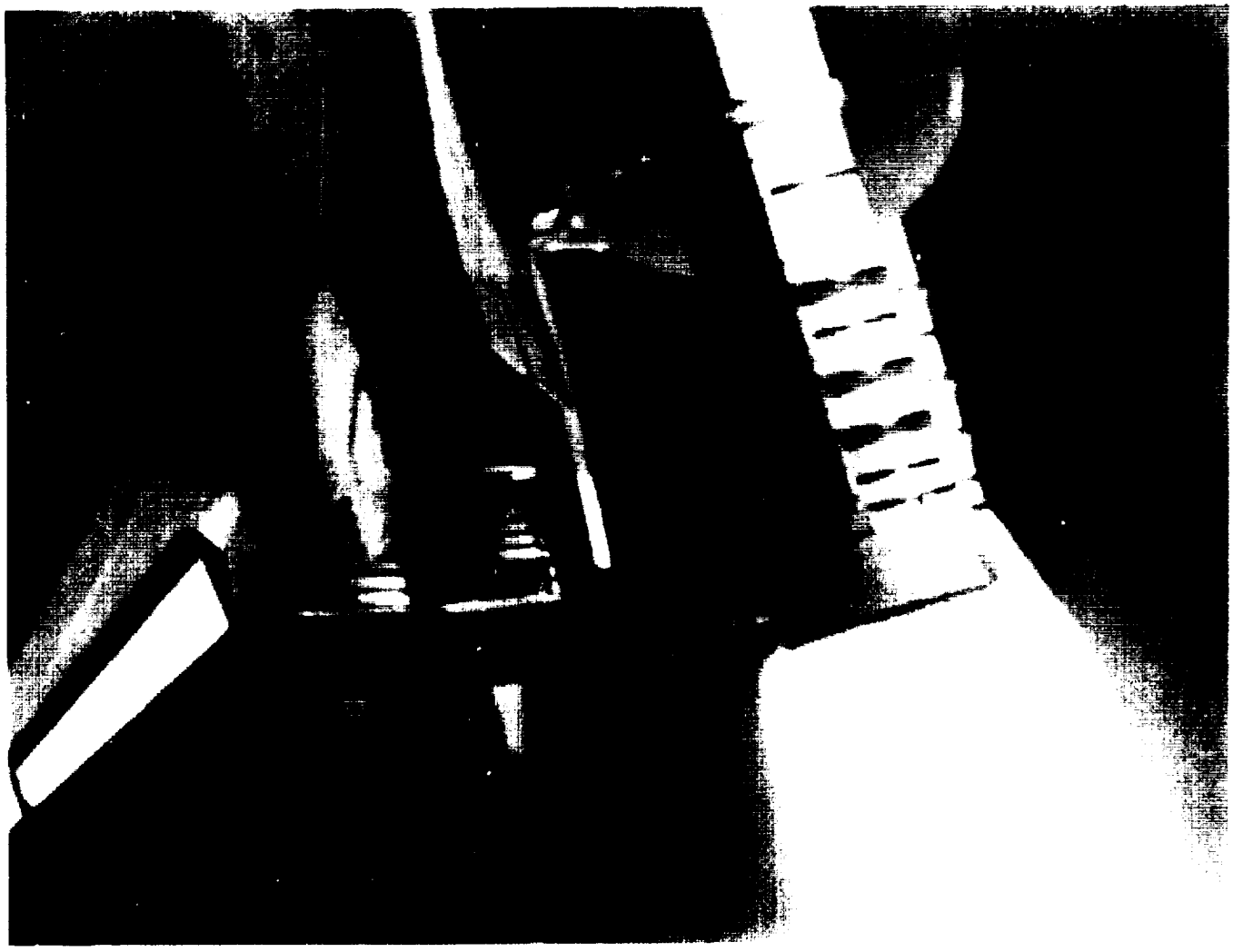


Photo 6 : Umbilical Purge Barrier Material

ET/ORB umbilical purge barrier (baggie) material fell aft during and after the roll maneuver

Photo 7 : Localized Flow Condensation

ORIGINAL PAGE
COLOR PHOTOGRAPH

Photo 8 : Localized Flow Condensation Collar

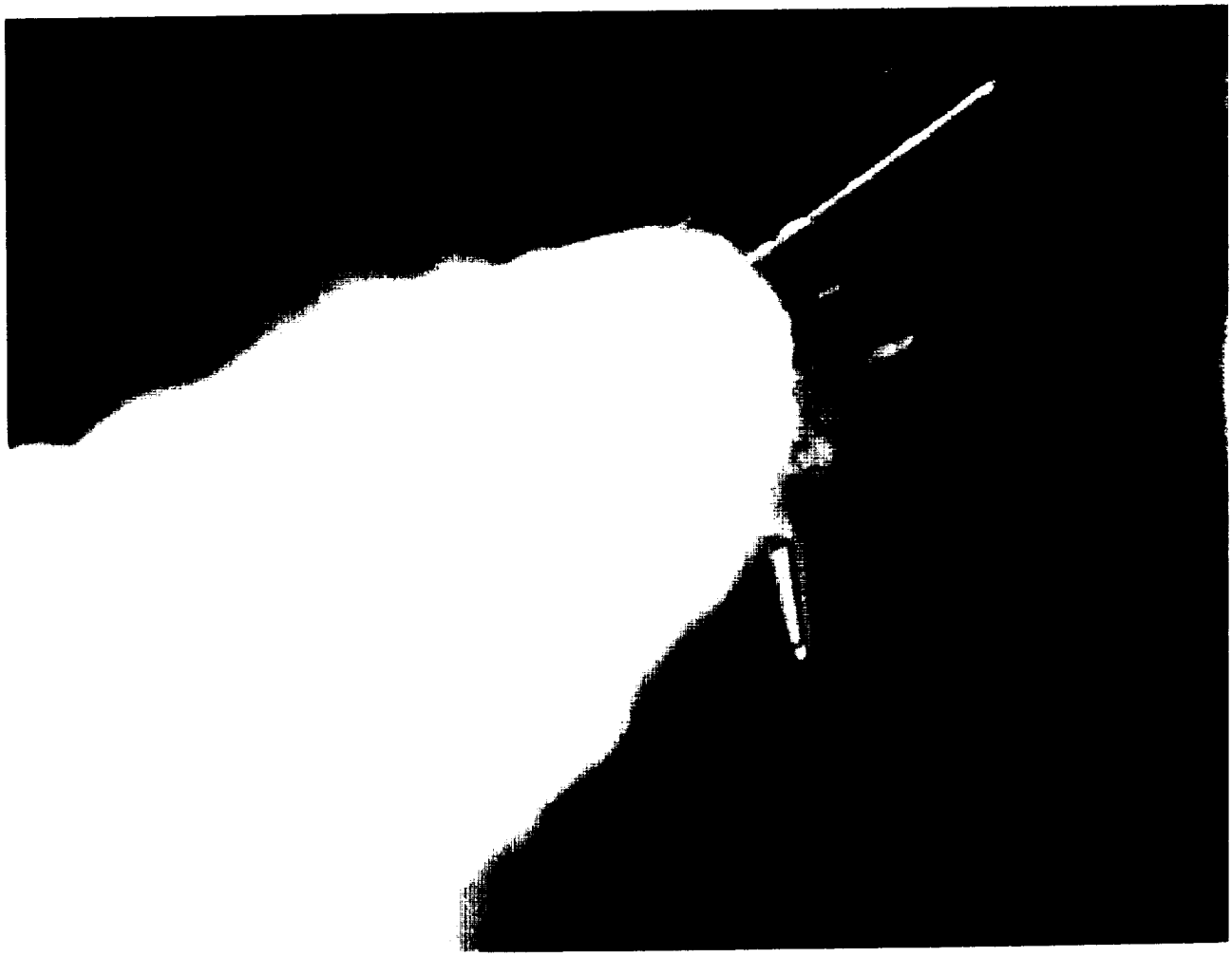


Photo 9 : Elevon Movement for Ascent Load Relief

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. One hand-held 35mm still image (no video) was obtained of the ET +Y-Z quadrant before the External Tank moved into darkness. OV-103 was not equipped to carry umbilical cameras.

No vehicle damage or lost flight hardware was observed that would have been a safety of flight concern. Review of the single image resulted in no IFA candidates.

Elevon divots, ranging in size from 6 to 10 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout in the +Y-Z quadrant. The divots were generally located in an area aft of the RSS antenna.

A large piece of frozen hydrogen was photographed, but the lack of reference in the field of view prohibited a calculation of size or distance from the camera.

5.3 LANDING FILM AND VIDEO SUMMARY

Eight 35mm films and three videos of landing were reviewed.

Orbiter performance on final approach appeared normal. There were no anomalies when the landing gear was extended with the exception of two thermal barriers lost from the main landing gear wheel wells. This event was not visible in the landing films due to atmospheric haze. Touchdown of the left and right main gear was nominal and virtually simultaneous.

The drag chute was deployed after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth.

Photo 10 : On-Orbit View of External Tank

The BSM burn scar on the LO2 tank was typical. No anomalies were observed on the LO2 and LH2 tank acreage. Note elevon divots in the LH2 tank-to-intertank flange closeout.

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 12-13 September 1994. From a debris standpoint, both SRB's were in good condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS but had 18 MSA-2 debonds over fasteners and 2 debonds over acreage (Figure 1). Hypalon paint was blistered/missing where BTA closeouts had been applied. Some of the underlying BTA was lightly sooted. All BSM aero heat shield covers had locked properly in the fully opened position.

The RH forward assembly MSA-2 acreage exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing from areas where BTA closeouts had been applied. No pins were missing from the frustum severance ring.

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. Water impact cracked the stiffener rings and caused the loss of foam from the stiffener rings and ETA rings. Splice plate closeouts were intact and no K5NA material was missing.

A 2" x 1" x 1.5" cavity was present in the ETA ring forward surface TPS near the upper strut. Crushed foam inside the cavity appeared charred and may be indicative of a debris impact early in flight. Post flight laboratory analysis revealed no embedded material, particles, or residue. The cavity/debris impact damage site was most likely caused by ice.

Phenolic material on the kick ring had delaminated. Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered/missing from areas where BTA had been applied. K5NA was missing from the BSM nozzles. A small ordnance debris fragment prevent the HDP #1 Debris Containment System (DCS) plunger from seating completely. Post flight disassembly of the DCS revealed 99 percent of the ordnance debris had been retained. The other three DCS plungers were seated and appeared to have functioned properly.

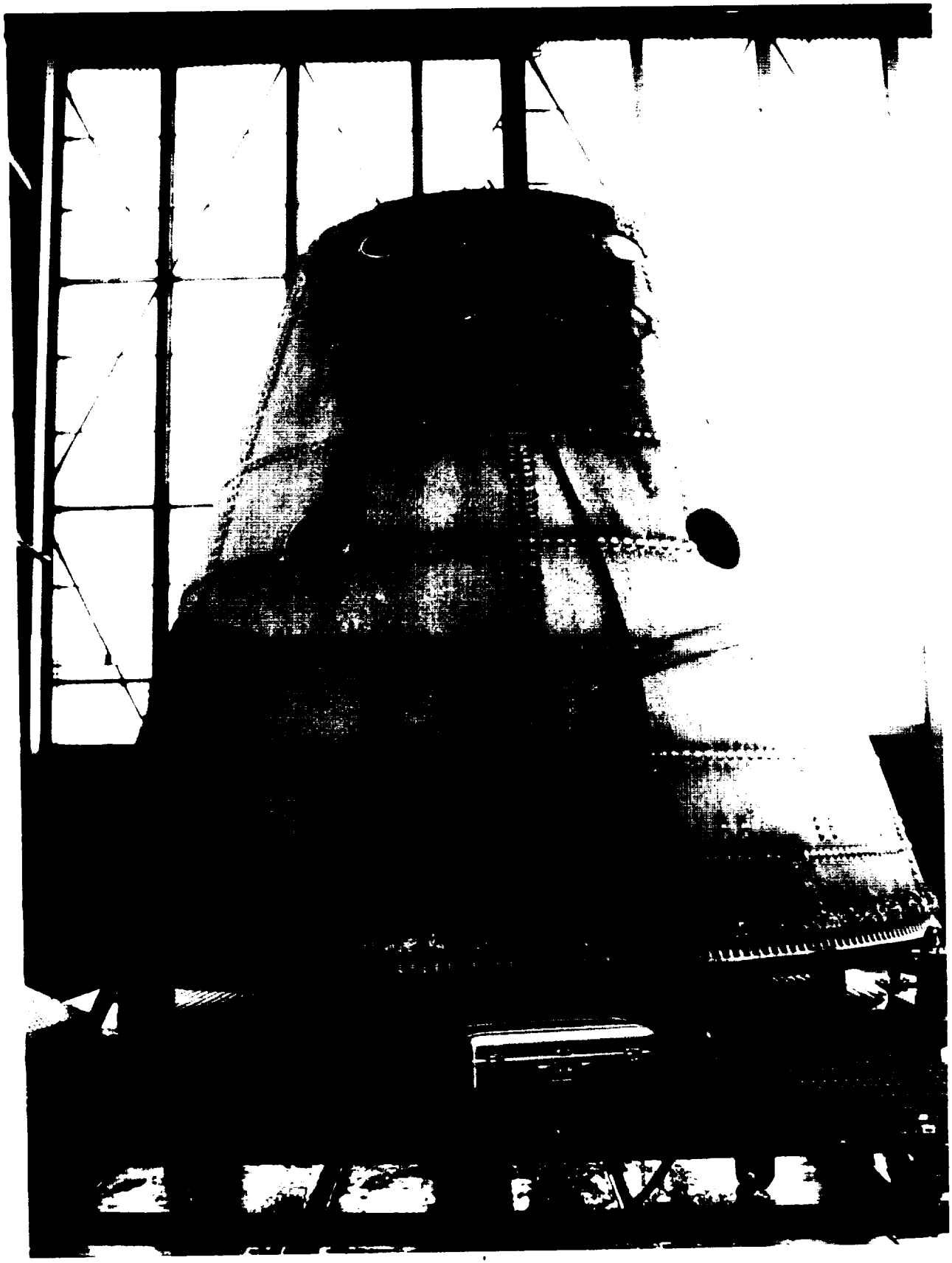


Photo 11 : RH SRB Frustum

The RH frustum was missing no TPS but had 18 MSA-2 debonds over fasteners and 2 debonds over acreage. The BSM aero heat shield covers had locked in the fully opened position.

Photo 12 : RH Aft Booster/ Aft Skirt

Photo 13 : Blistered/Missing Hypalon Paint

Hypalon paint was blistered/missing where BTA closeouts had been applied. Some of the underlying BTA was lightly sooted.

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 18 MSA-2 debonds over fasteners (Figure 2). Hypalon paint was blistered/missing where BTA closeouts had been applied. Some of the underlying BTA was lightly sooted. All BSM aero heat shield covers had locked properly in the fully opened position.

The LH forward assembly MSA-2 acreage exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing from areas where BTA closeouts had been applied. No pins were missing from the frustum severance ring.

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. Water impact cracked the forward stiffener ring and caused the loss of foam from the stiffener rings and ETA rings. Splice plate closeouts were intact and no K5NA material was missing. The systems tunnel cover to aft skirt "rooster tail" interface on the LH SRB was damaged by water impact.

Phenolic material on the kick ring had delaminated. Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered/missing from areas where BTA had been applied. K5NA was missing from the BSM nozzles. All Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

SRB Post Launch Anomalies are listed in Section 9.

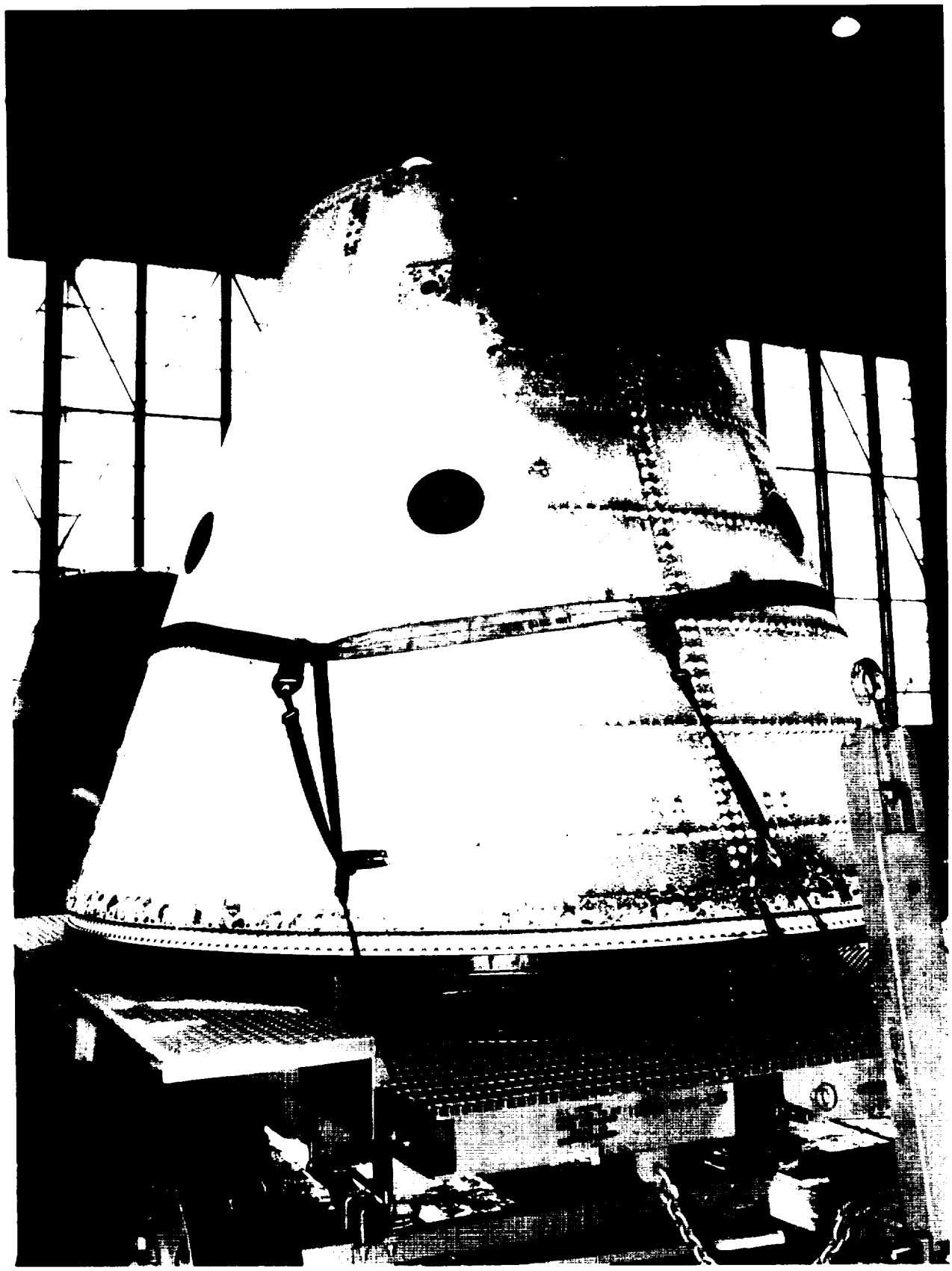


Photo 14 : LH SRB Frustum

The LH frustum was missing no TPS but had 18 MSA-2 debonds over fasteners. Hypalon paint was blistered/missing where BTA closeouts had been applied. All BSM aero heat shield covers had locked in the fully opened position.

Photo 15 : LH Aft Booster / Aft Skirt

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-103 (Discovery) was conducted 20-22 September 1994 at the Dryden Flight Research Center/ Edwards Air Force Base on runway 04 and in the Mate/Demate Device. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 150 hits, of which 19 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 48 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates the total number of hits was slightly greater than average and the number of hits 1-inch or larger was less than average (reference Figures 3-6).

The following table breaks down the STS-64 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	18	116
Upper surface	0	1
Right side	1	7
Left side	0	2
Right OMS Pod	0	16
Left OMS Pod	0	8
TOTALS	19	150

The Orbiter lower surface sustained a total of 116 hits, of which 18 had a major dimension of 1-inch or greater. A total of 53 hits occurred just aft of the LH2 ET/ORB umbilical. Two of these damage sites had a major dimension greater than 1-inch. Cluster of hits aft of the LH2 and LO2 ET/ORB umbilicals are believed to be impacts from umbilical ice and purge barrier (baggie) material.

An 18-inch section of main landing gear door thermal barrier, including carrier panel, was missing from the aft inboard area of both left and right gear wells (IFA STS-64-V-08: PR LWING-3-20-5466 and PR RWING-3-20-4896). These pieces (part numbers V070-199052-013 and -014) fell from the vehicle during gear deployment and were subsequently found approximately 4000 feet from the runway 04 threshold. The RH thermal barrier assembly apparently caused 5 damage sites on the tiles aft of that location. The PR's were closed by modifying the thermal barrier assembly installation procedures.

A 12-inch section of 1307 bulkhead thermal barrier was missing from the lower right position just forward of the RH OMS pod. The thermal barrier apparently caused 3 damage sites just aft of that location.

No tile damage from micrometeorites or on-orbit debris was identified during the inspection.

No TPS damage was attributed to material from the wheels, tires, or brakes. The tires were in excellent condition after a landing on the concrete runway.

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

DEBRIS DAMAGE LOCATIONS

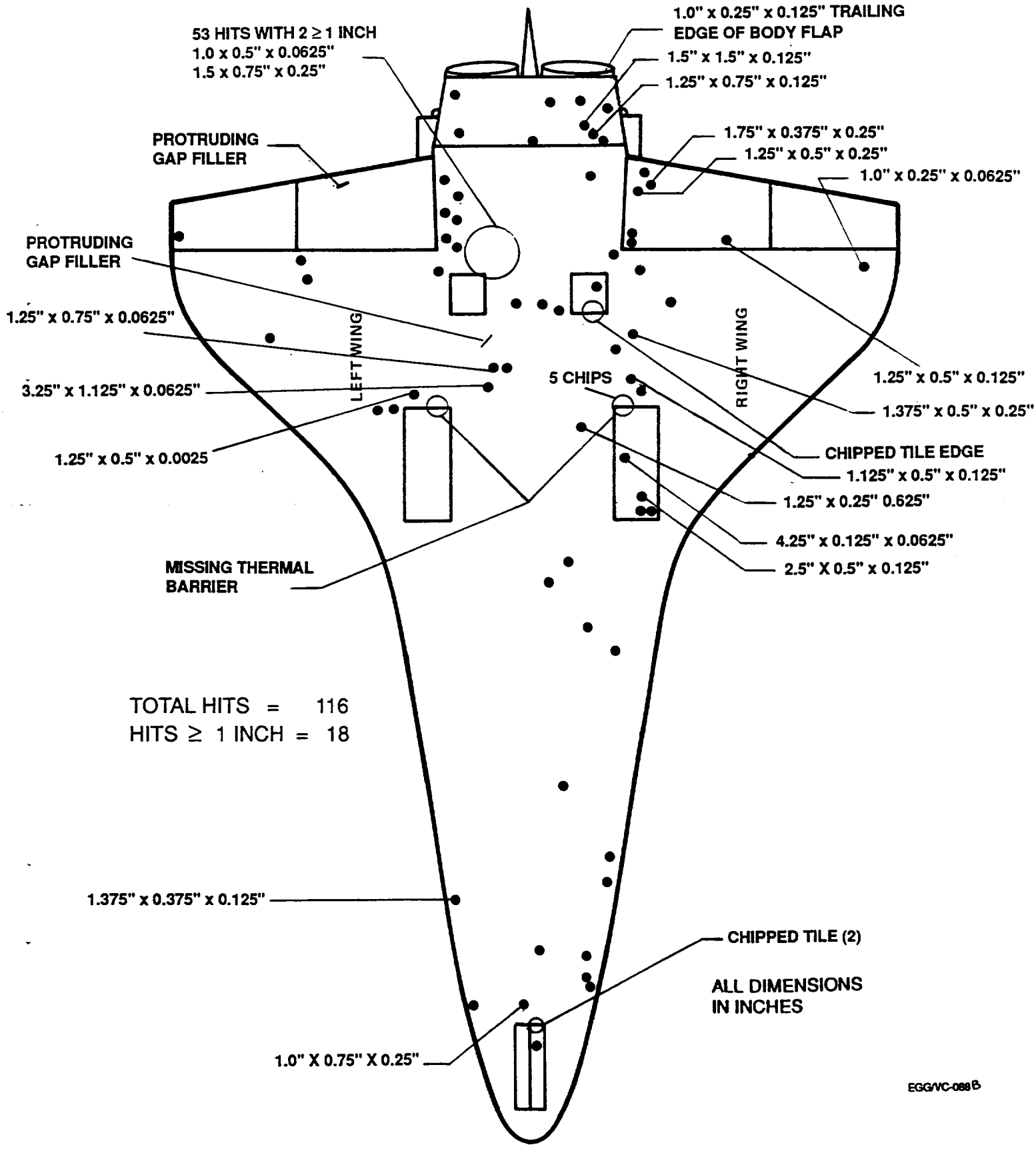


Figure 3 : Orbiter Lower Surface Debris Map

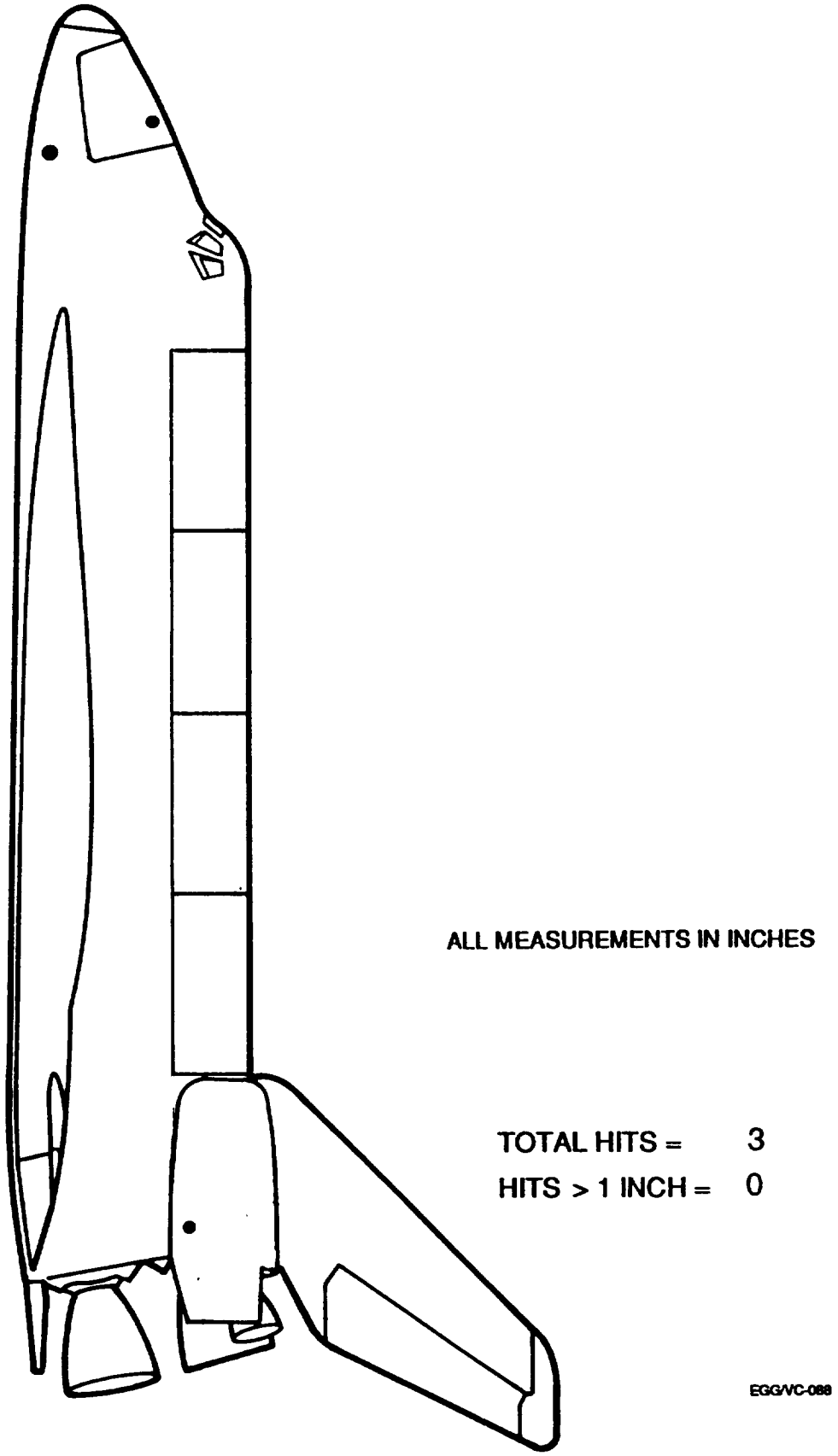


Figure 5 : Orbiter Left Side Debris Map

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
AVERAGE	14.0	90.2	21.4	131.3
SIGMA	7.3	44.1	10.2	57.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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

Figure 7 : Orbiter Post Flight Debris Damage Summary

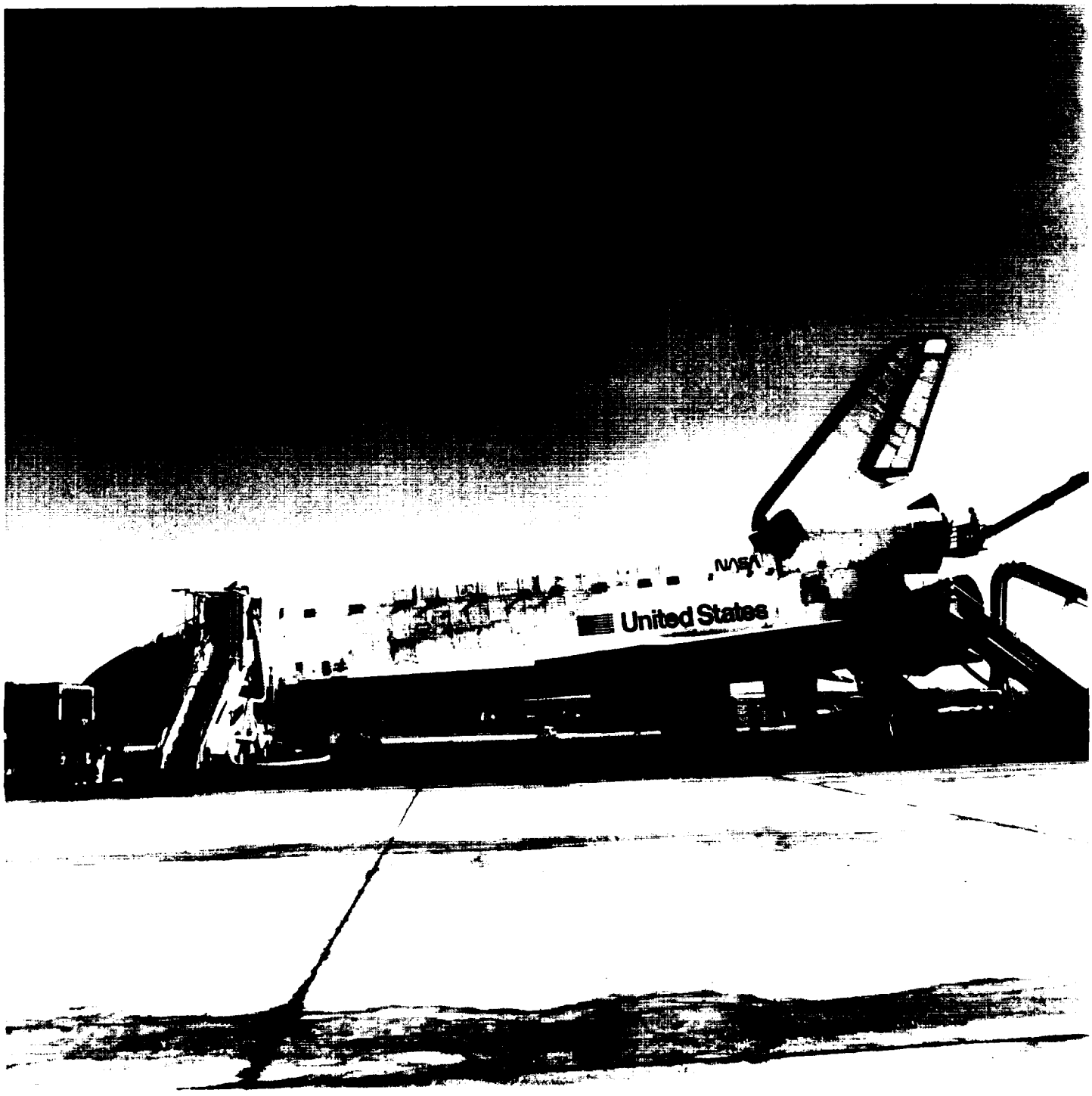


Photo 16 : Overall View of Orbiter Left Side

ORIGINAL PAGE
COLOR PHOTOGRAPH

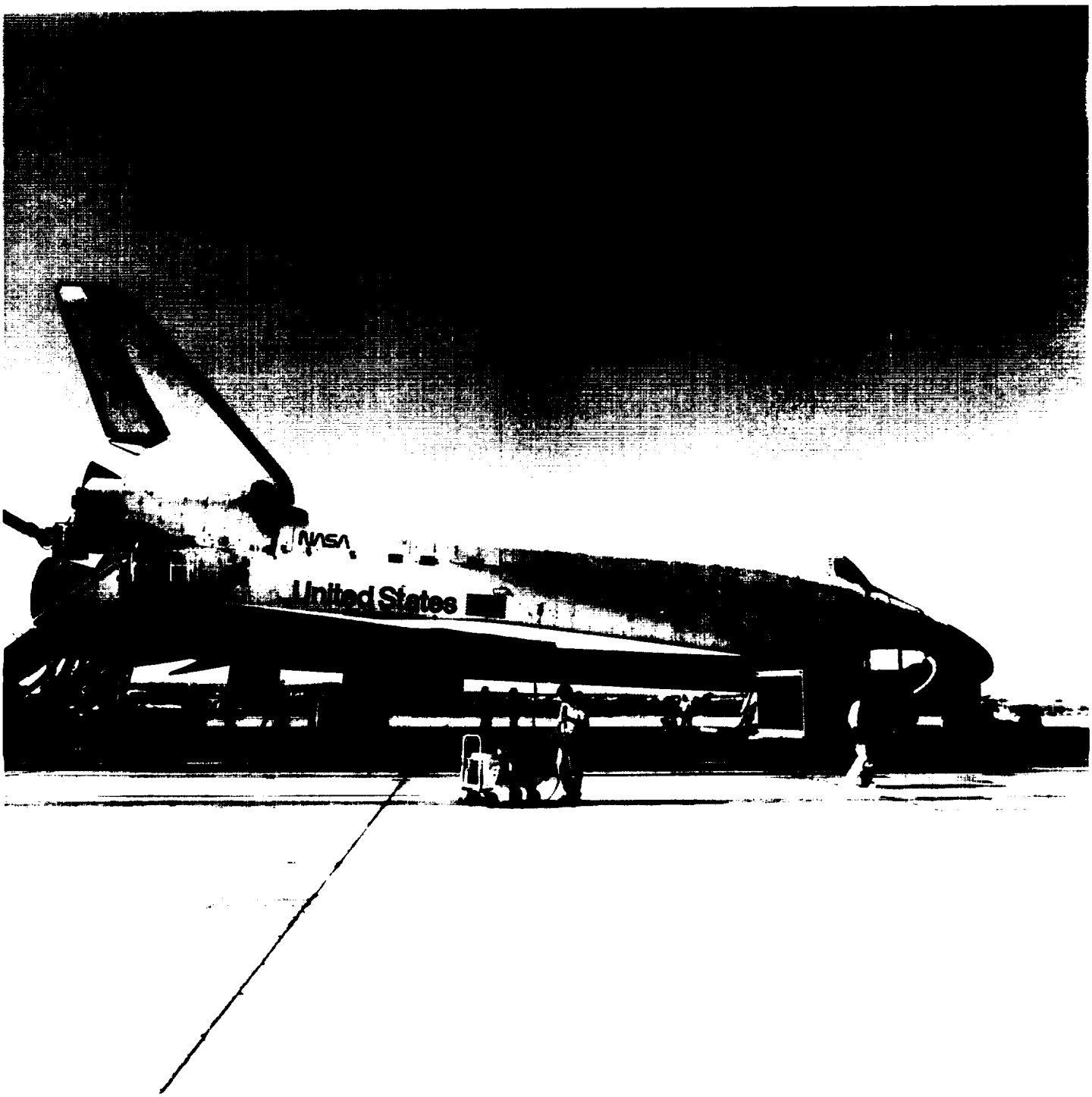


Photo 17 : Overall View of Orbiter Right Side

ORIGINAL PAGE
COLOR PHOTOGRAPH

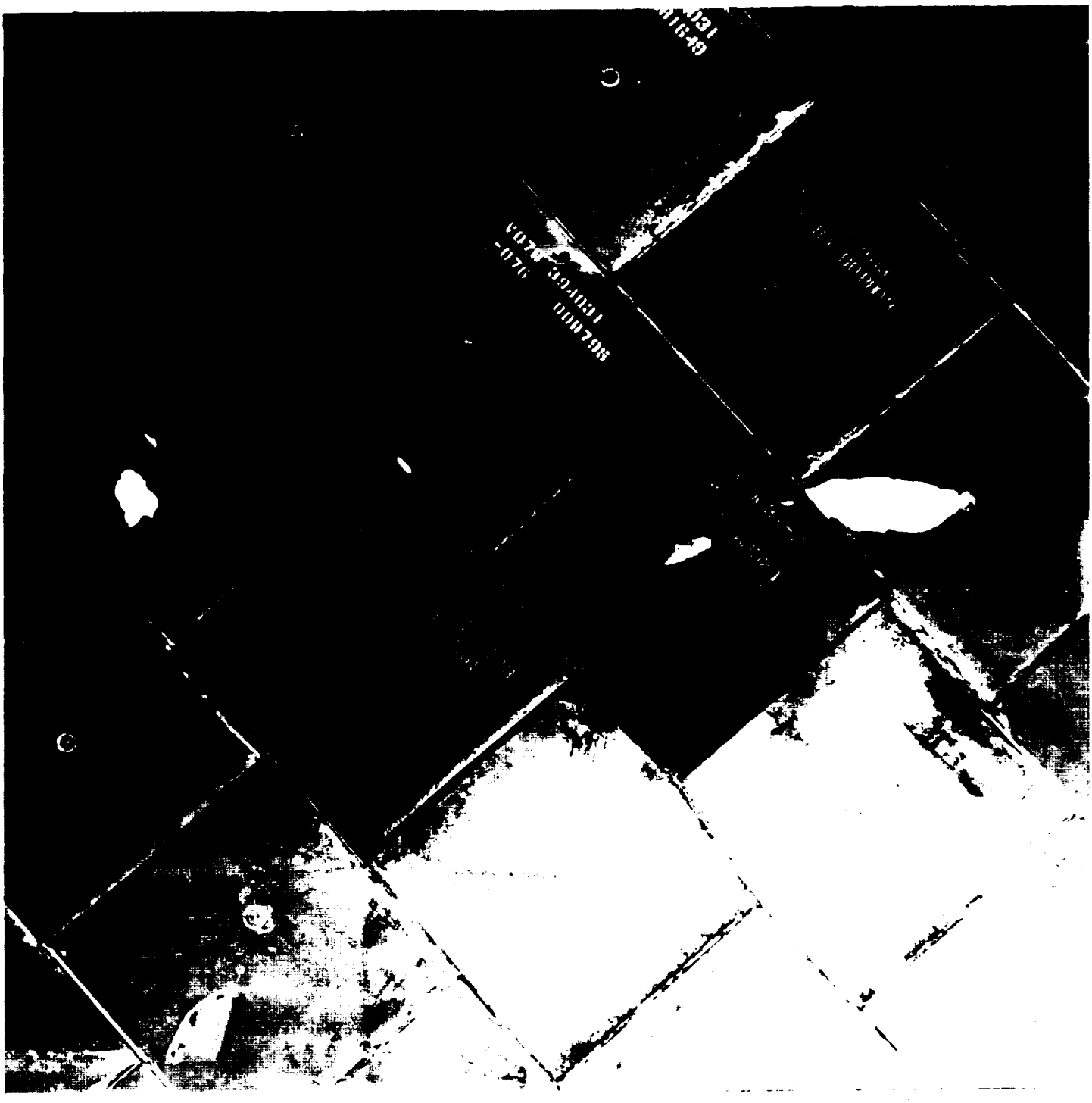


Photo 18 : Damage to Lower Surface Tiles

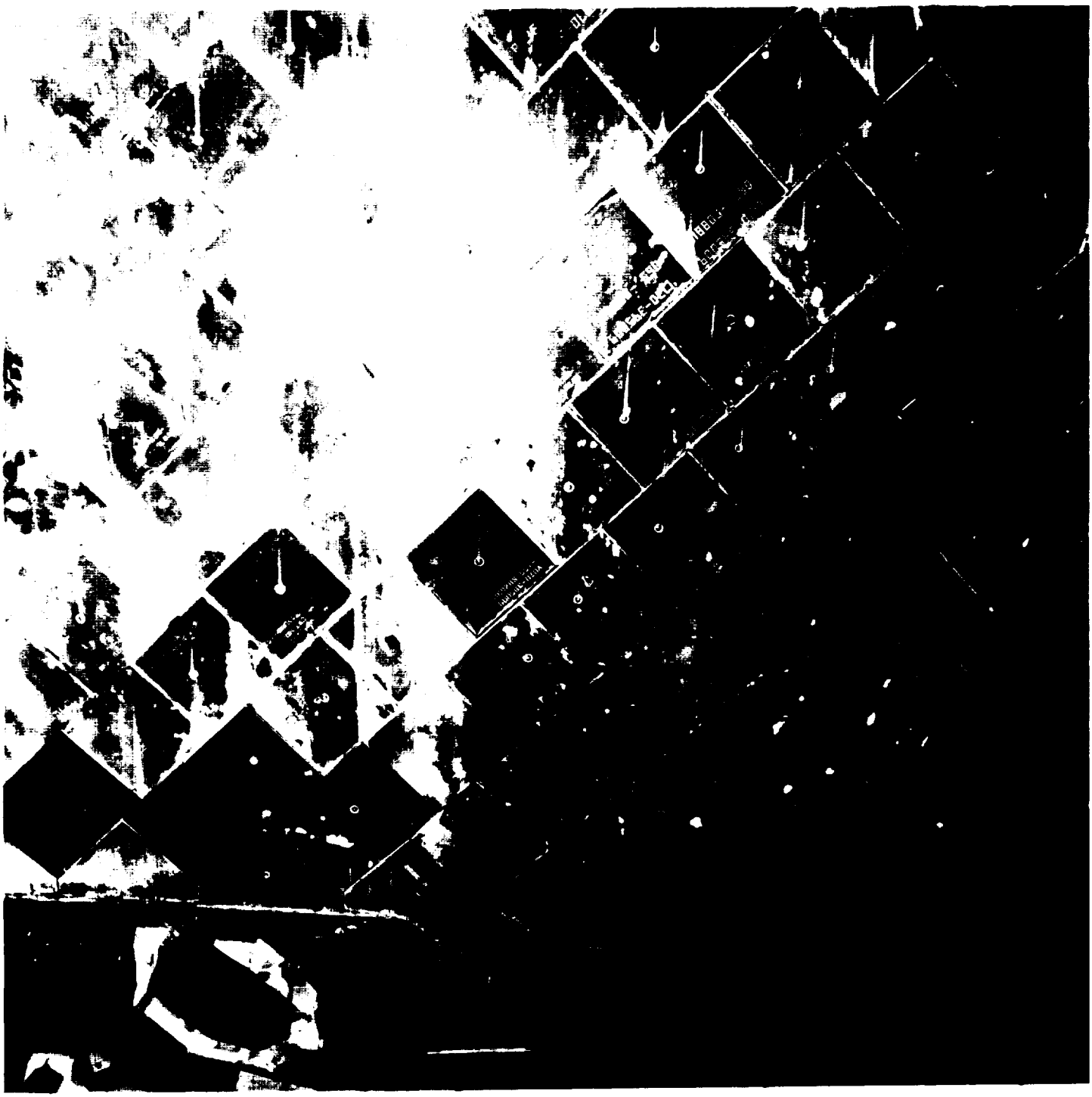


Photo 19 : Tiles Damaged by Ice Particles

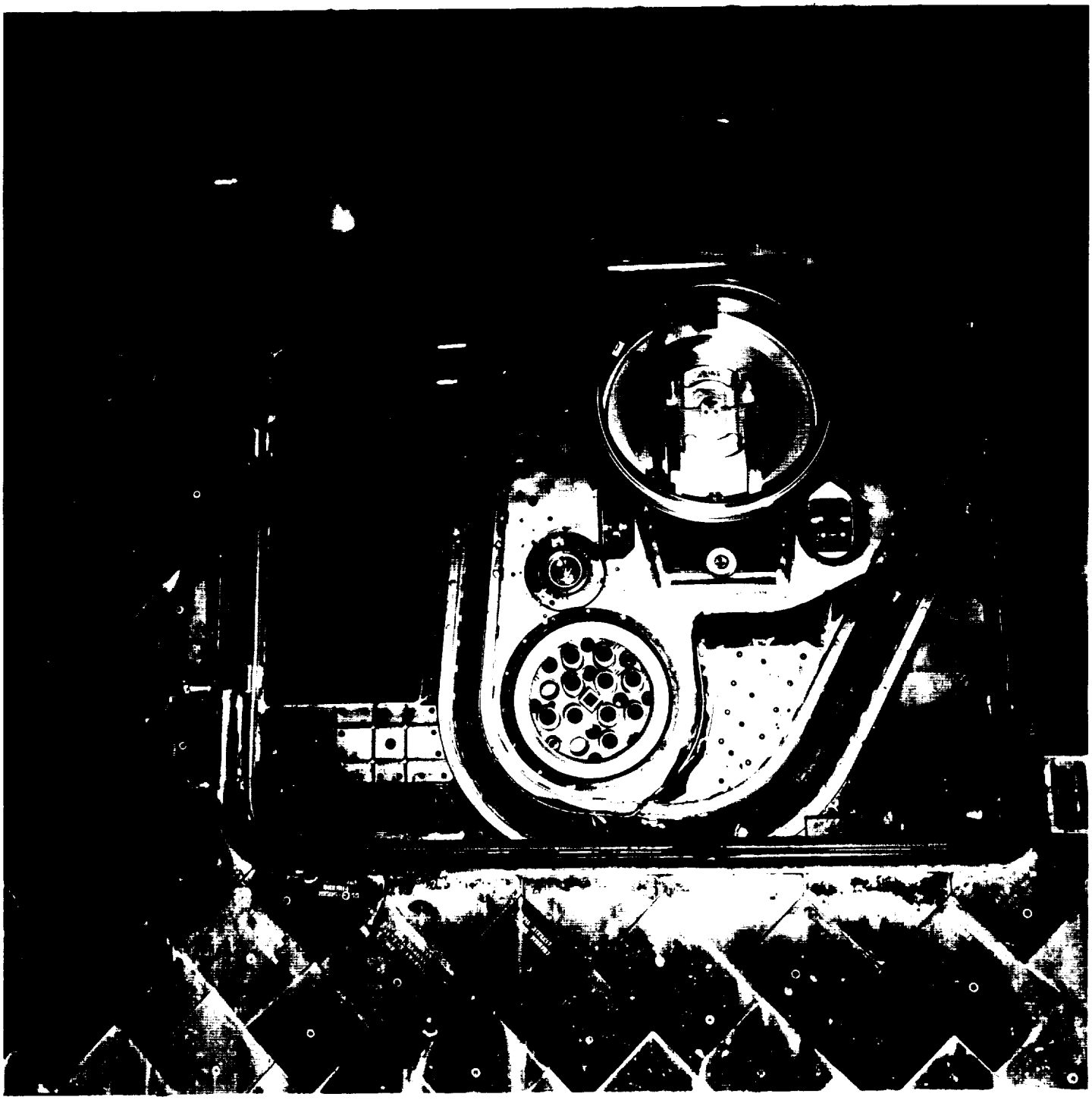


Photo 20 : LO2 ET/ORB Umbilical

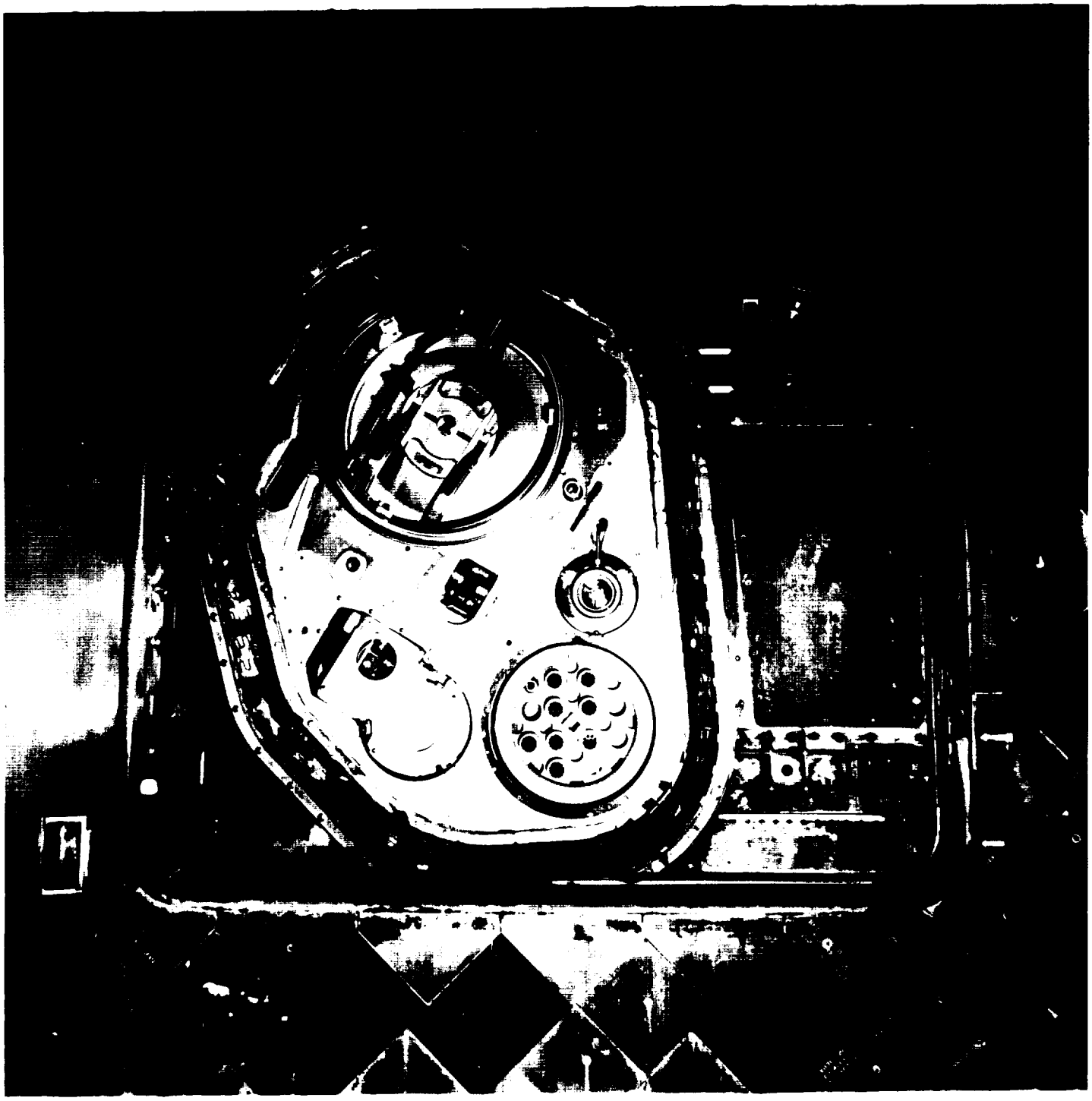


Photo 21 : LH2 ET/Orbiter Umbilical

Photo 22 : Window Streaks and Perimeter Tile Damage

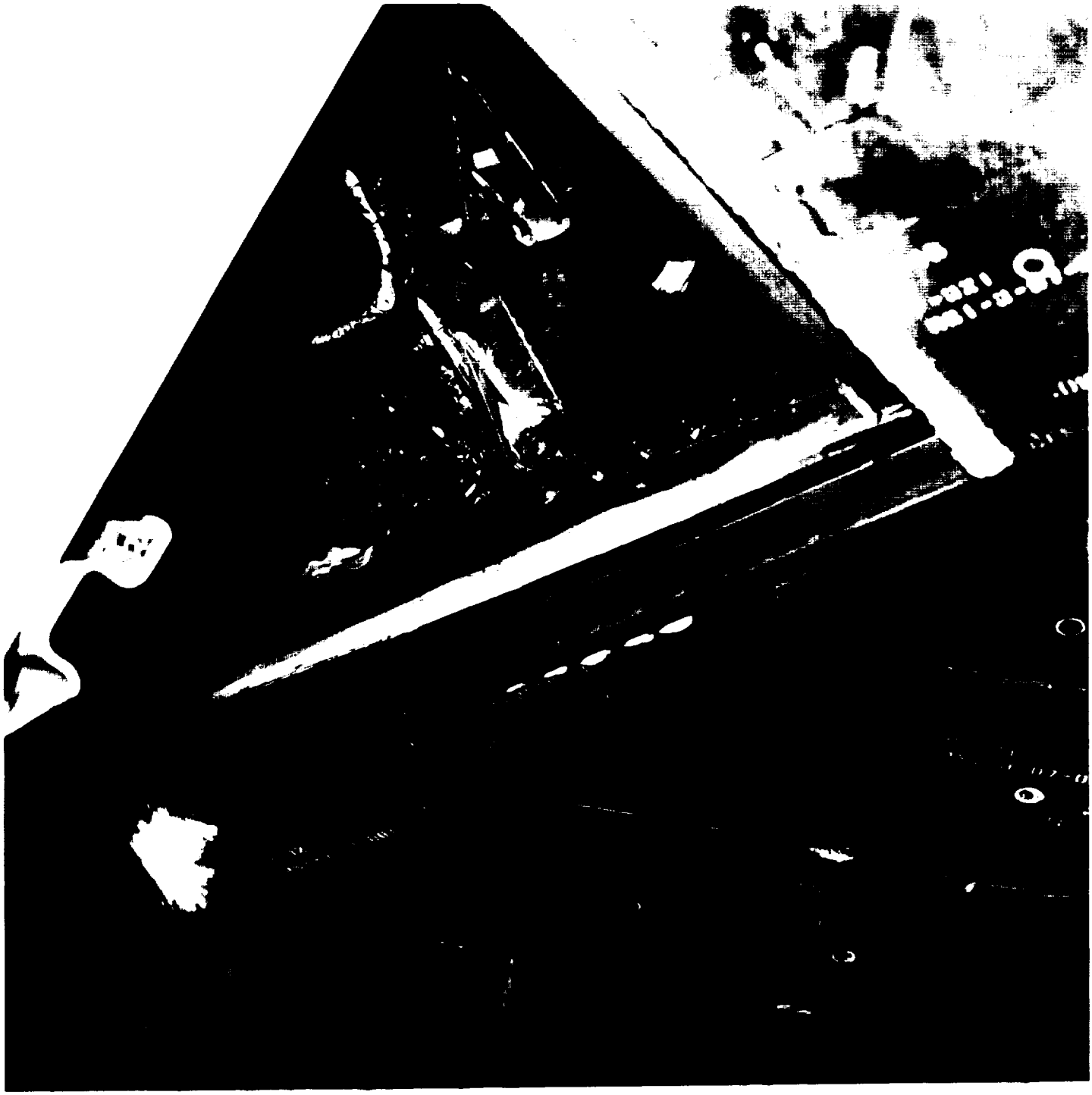


Photo 23 : Thermal Barrier Missing from RH MLG Wheel Well

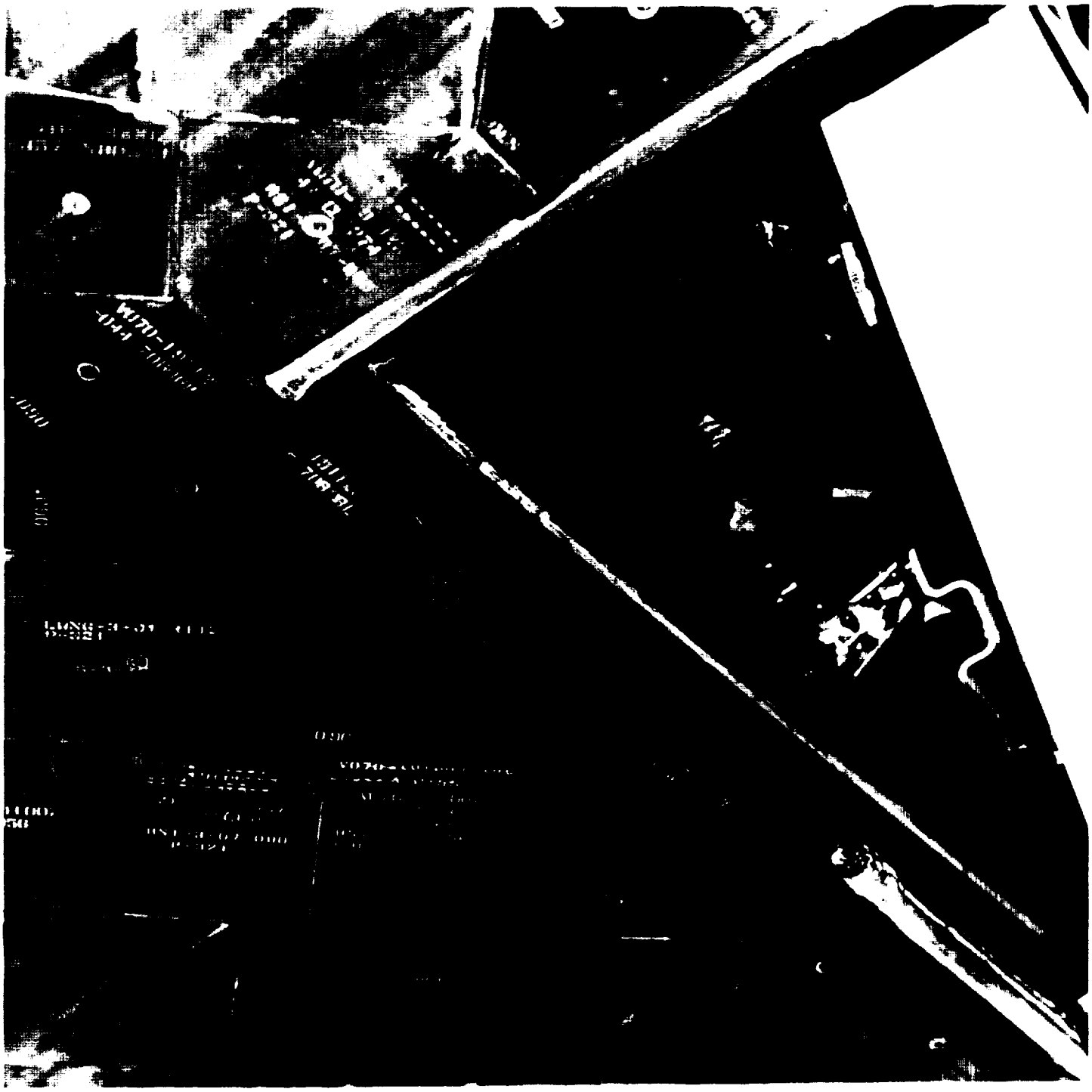


Photo 24 : Thermal Barrier Missing from LH MLG Wheel Well

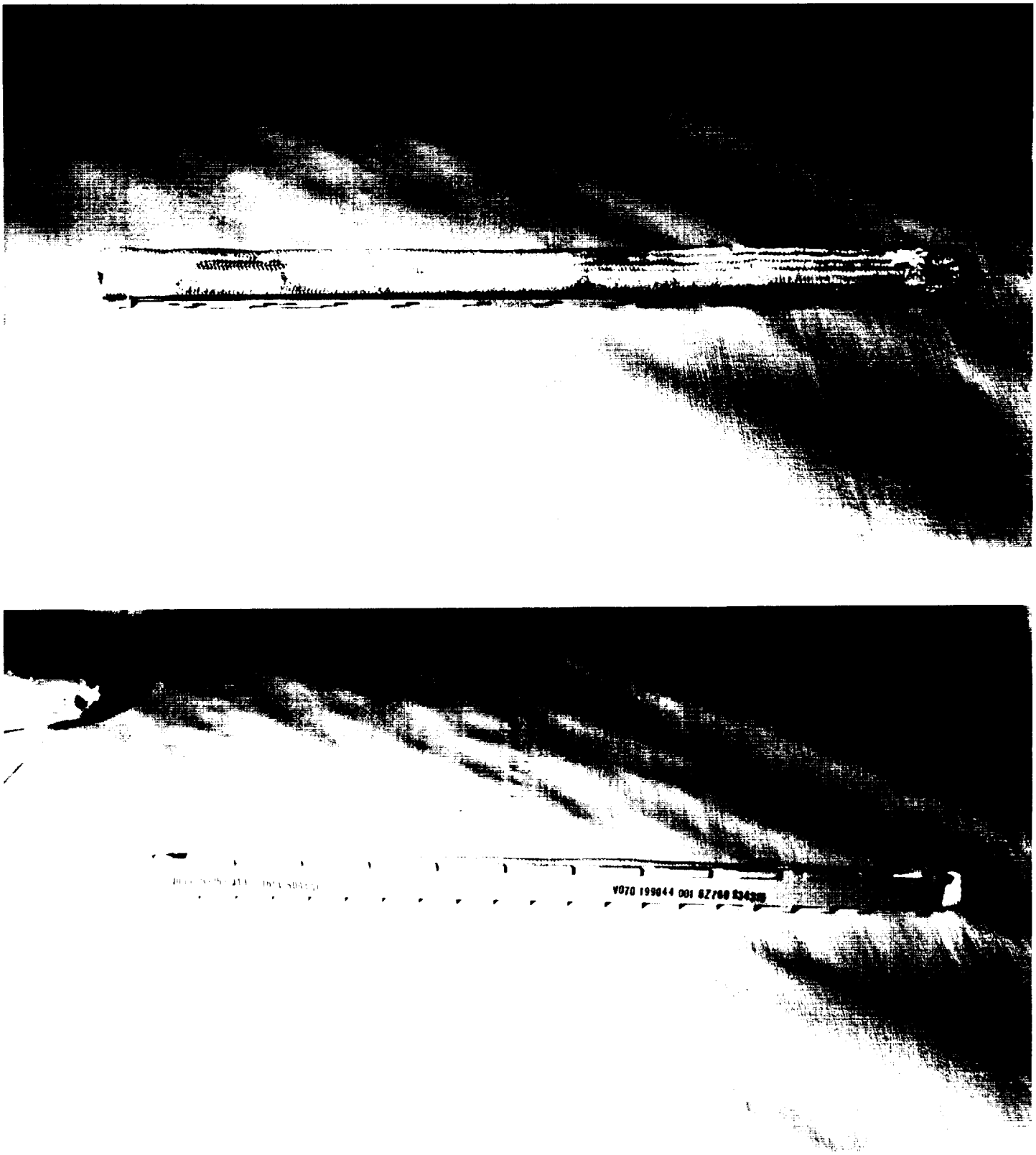


Photo 25 : Thermal Barriers Missing from MLG Wheel Wells

8.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-103 Discovery during the STS-64 post landing debris assessment at Dryden Flight Research Facility, California. The submitted samples consisted of 8 wipes from Orbiter windows 1-8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

8.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile, RTV and glass insulation), window polish residue, building-type insulation fibers, paints and primer from various sources. An interesting finding was the variety of paint particulate colors: black, white, red, blue, green, and yellow. The yellow paint particulate contained lead, which is typically found in facility/GSE paint. The metallic particulate, found in the window #4 sample, contained silver (discussed as a new finding). There was no apparent vehicle damage related to these residuals.

8.2 STS-64 ORGANIC ANALYSIS

The results of the STS-64 organic analysis are included in this report (reference Figure 9). Identified materials included those associated with window covers (plastic polymers), RTV from RCS thruster nozzle cover adhesive and Orbiter Thermal Protection System, and paint from various sources. An interesting finding was the presence of Teflon material, though no exact source has been determined for this particulate. There was no apparent vehicle damage related to these residuals.

8.3 NEW FINDINGS

This set of post-flight debris residual samples led to one new finding, which was obtained in the sample from Orbiter window #4. A small amount of silver metallic particulate was detected. Silver metal is not normally associated with external Shuttle coatings or processing, but is used to some degree in the payload community. Although the precise source has not yet been determined, the silver particulate does not appear to be related to any debris damage.

9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, five post launch anomalies, including one In-Flight Anomaly (IFA), were observed on the STS-64 mission.

9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. 4-foot section of handrail and an 8-foot section of cable tray cover were found on the southwest corner of the pad apron.

9.2 EXTERNAL TANK

1. No items.

9.3 SOLID ROCKET BOOSTERS

1. The RH frustum was missing no TPS but had 18 MSA-2 debonds over fasteners and two debonds over acreage.

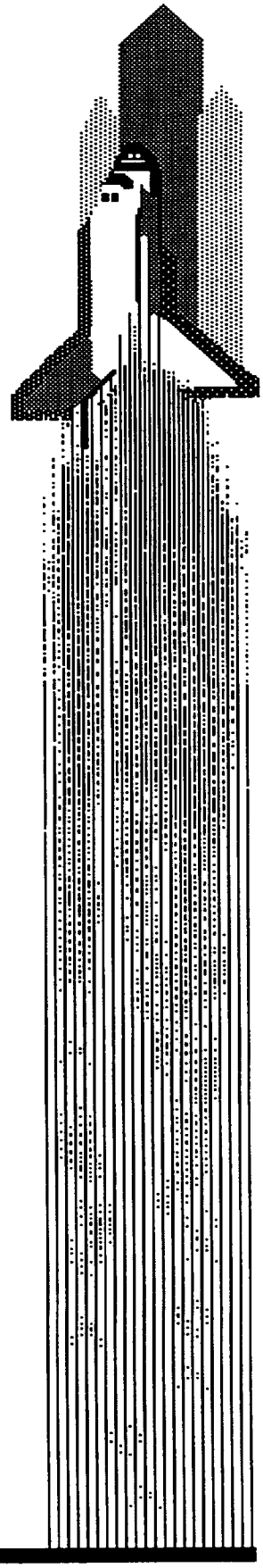
2. The LH frustum was missing no TPS but had 18 MSA-2 debonds over fasteners.

9.4 ORBITER

1. An 18-inch section of main landing gear door thermal barrier, including carrier panel, was missing from the aft inboard area of both left and right gear wells (IFA STS-64-V-08: PR LWING-3-20-5466 and PR RWING-3-20-4896). These pieces (part numbers V070-199052-013 and -014) fell from the vehicle during gear deployment and were subsequently found approximately 4000 feet from the runway 04 threshold. The RH thermal barrier assembly apparently caused 5 damage sites on the tiles aft of that location. The PR's were closed by modifying the thermal barrier assembly installation procedures.

2. A 12-inch section of 1307 bulkhead thermal barrier was missing from the lower right position just forward of the RH OMS pod. The thermal barrier apparently caused 3 damage sites just aft of that location.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY



Space Shuttle

Photographic and Television Analysis Project

STS-64 Summary of Significant Events

October 28, 1994

Table of Contents

1.0 OV-103 STS-64 FILM/VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

Discovery (OV-103) launched on mission STS-64 from Pad B at 22:22:54.989 Coordinated Universal Time (UTC) on September 9, 1994 (day 252) as seen on camera E-9. Solid rocket booster (SRB) separation occurred at 22:24:57.458 UTC as seen on camera E-207.

On launch day, 22 videos were screened. Following launch day, 52 films were reviewed. Camera E-41 and E-79 films were not received due to camera problems.

No anomalies were observed during launch.

Detailed Test Objective (DTO) -312 photography of the STS-64 external tank (after separation) was acquired with a 35 mm Nikon camera with a 300 mm lens and a 2x extender (method 3). Eleven exposures on magazine 01 were present. The external tank was visible in only one frame (frame 03) showing the +y/-z side of the ET. See Section 2.4.1, Analysis of Handheld Photography of the ET (Task 6), for details.

1.1.2 On Orbit

A damaged tile was reported by the crew on the port side OMS pod and a white piece of debris was noted on the starboard side of the vertical stabilizer. Reviews of the video downlink during the SPIFEX experiment showed a slight discoloration of the felt reusable surface insulation (FRSI) blanket on the forward portion of the OMS pod at the 11 o'clock position as viewed from the crew cabin.

The debris seen near the vertical stabilizer is similar to debris seen on past missions and was probably ice formed during a water dump. See Section 2.5, On Orbit Events, for details.

1.1.3 Landing

The opportunities for landing of STS-64 on September 19 and 20, 1994 at the Kennedy Space Center (KSC) were waived due to weather constraints.

Discovery landed on runway 04 at Edwards Airforce Base on September 20, 1994 (day 263). Five videos of the Orbiter's approach and landing were received. NASA Select, which uses multiple real-time views, was also received. No anomalies were detected during the screening of the replays. Left main gear touchdown was at 21:12:51.347 UTC, right main gear touchdown occurred at 21:12:51.514 UTC and nose wheel touchdown was at 21:13:03.259 UTC as seen on camera DTV-2. Wheel stop was noted at 21:13:51.972 UTC on camera LRO-1.

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

The deployment of the drag chute appeared as expected.

2.1.3 Debris after Liftoff

(Cameras E-17, E-35, E-52, E-59, E-63, E-212, E-213, E-218, E-220, E-223, E-224, OTV-161, OTV-170, KTV-13, ET-207, ET-208, ET-212)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) at liftoff, throughout the roll maneuver, and beyond on the launch tracking views. Most of the debris sightings were probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. None of the debris was observed to strike the vehicle. No follow-up action has been requested. Two of the more note worthy pieces of debris are described below.

2.1.3.1 Debris between 16 and 30 Seconds MET

(Camera E-224)

Four unidentified pieces of light colored debris (origin unknown) were seen near the SRB exhaust plume at 16.3, 20.0, 25.0, and 29.5 seconds MET. A light colored piece of debris was seen falling from near the forward one-third of the RSRB at 28.14 seconds MET. None of these debris pieces were seen to strike the SLV. It is possible that these objects were birds that appeared to be debris because of the view angle. No follow-up action was requested.

2.1.3.2 Debris near SRB Exhaust Plume

(Cameras E-218, E-220)

Two light colored pieces of debris were seen falling aft of the SLV and along the SRB plume at approximately 75 seconds MET. A large light colored piece of debris was seen falling aft of the SLV and into the SLV exhaust plume at approximately 76 seconds MET.

Figure 2.1.3.2 **Debris near SRB Exhaust Plume**
(Camera E-220)

2.2 MLP EVENTS

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen)
(Cameras OTV-163, OTV-171, E-3, E,-16, E-17, E-19, E-20, E-30, E-36, E-76, E-77)

Orange vapor (probably free burning hydrogen) was seen between the body flap and the SRBs at T-5.444 seconds MET. Orange vapor was seen above the rims of the SSMEs, near the vertical stabilizer, surrounding the left OMS nozzle, and forward of the aft edge of the left OMS pod at T-5.176 seconds MET. This event has been noted on past missions and would become a concern if the vapor was seen as high as the umbilical areas. On this mission, however, the vapor was well below the umbilicals. No follow up action was requested.

2.2.2 Orange Glow/Vapor in SSME Exhaust Cloud South of MLP
(Camera E-36)

An orange glow/vapor was seen in the SSME exhaust cloud south of the MLP prior to SRB ignition. No follow up action was requested.

2.3 ASCENT EVENTS

2.3.1 Body Flap Motion *(Task #4)*

2.3.1.1 Body Flap Motion on the Pad *(Cameras E-17, E-18)*

A continuing historical analysis of OV-103 missions is the driver for studying body flap motion seen on the pad.

A subjective comparison between this mission and others since reflight indicated only slight on-pad motion on STS-64. The time of maximum on-pad motion was determined to lie just after SSME ignition. Points defining the aft port and starboard edges of the body flap were chosen on every fourth frame over a period of 400 frames on cameras E-17 and E-18. This corresponded to approximately 1 second of actual data. In addition, a control point on the TSM was chosen to serve as a control for camera motion. Body flap thickness (assumed to lie in the plane of motion) was used as the scaling factor for this analysis. The maximum peak-to-peak motion measured approximately 0.8 inches on both the starboard and port sides.

A frequency-domain analysis was conducted to identify modes of vibration. Due to the high sampling rate (0.01 seconds) and short duration (1.0 second) of the acquired data, results within the frequency range of interest (0-20 hertz) are not of high enough resolution to be useful. A longer time interval and lower sampling rate will be used if time permits.

2.3.1.2 Body Flap Motion During Ascent *(Cameras E-207, E-212, E-213)*

Concerns about the cumulative effect of stresses from multiple missions are the driver for the body flap motion analysis. In addition, engineers at Edwards Air Force Base noted an asymmetric deflection in the flap at the conclusion of the STS-64 mission.

Camera E-207, fitted with a long lens, provided the best view of body flap motion seen during ascent to date. A subjective comparison between this mission and others since reflight indicated substantial motion on STS-64. Points defining the aft port and starboard edges of the body flap were chosen on every other frame over a period of 200 frames. This corresponded to a little over 3 seconds of actual data. In addition, two control points on the Orbiter fuselage were chosen to serve as a control for error measurements. SSME bell diameters (in the plane of motion) were used as scaling factors for this analysis. Note that although the data indicated significant motion, most of the measurements lay within the noise. However, substantial motion was visible when peaks reached higher than +/-3 standard deviations of the noise. The maximum peak-to-peak motion measured approximately 4.2 inches on the starboard side and 5.2 inches on the port side.

A frequency-domain analysis was conducted to identify modes of vibration. The data revealed the existence of several specific modes of vibration. Both the port and starboard data revealed peaks at 8.5 hertz (global rotation) and 10.5 hertz (local rotation). The significance of the presence of these modes depends upon the results of long term trend analysis. An attempt to isolate these frequencies will be performed using bandpass filters as time allows.

2.3.2 Linear Optical Effect
(Cameras E-207, E-208, E-212, E-223, KTV-13, ET-208)

Linear optical effects were seen between 67 and 96 seconds MET. Engineers at JSC have previously attributed this event seen on earlier missions to the manifestation of shock waves around the SLV. No follow-up action was requested.

2.3.3 Recirculation
(Camera E-207)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all previous missions. Recirculation on STS-64 was observed between approximately 100 and 104 seconds MET on camera E-207.

2.3.4 Orange Flashes in SRB Exhaust Plume
(Camera E-208, E-212)

Several orange colored flashes were seen in the SRB exhaust plume approximately three seconds prior to SRB separation. Orange colored flashes have been seen on previous mission films in the SRB exhaust plume prior to SRB separation. No follow-up action was requested.

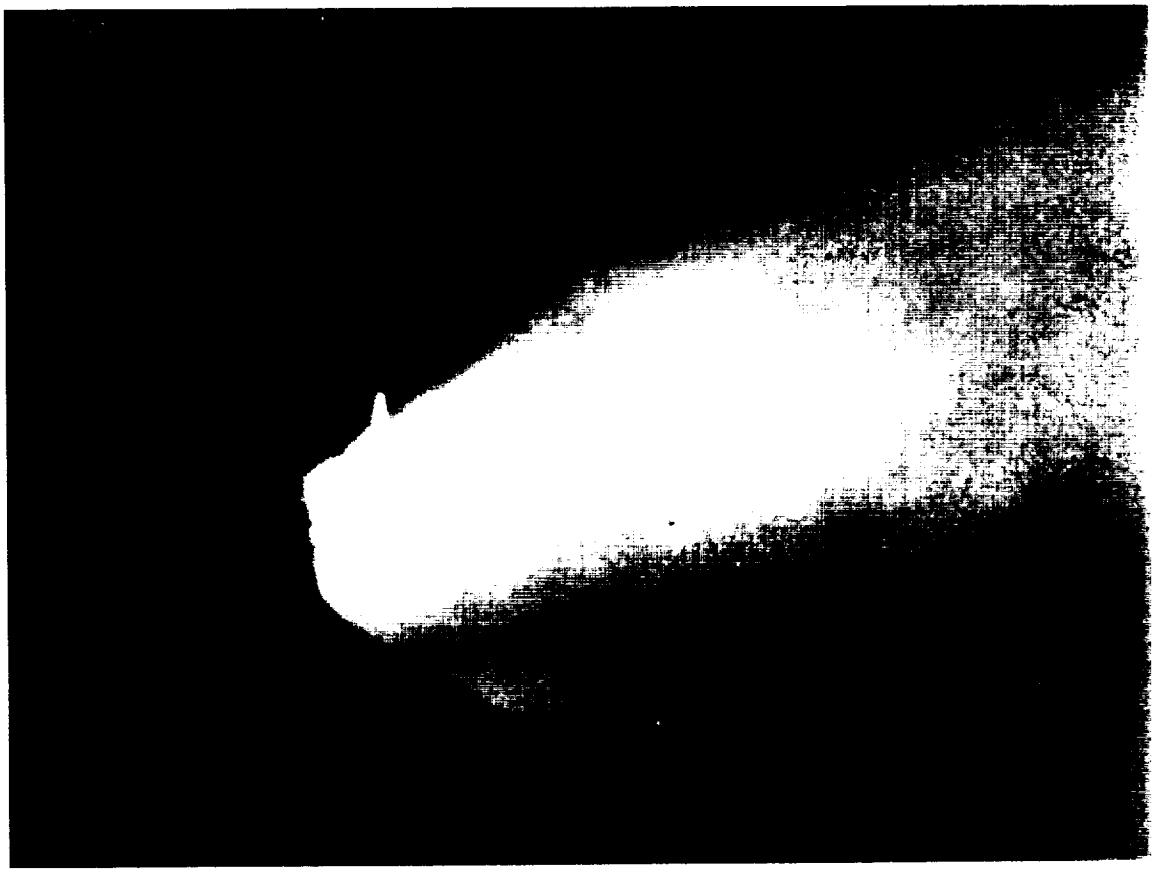


Figure 2.3.4 **Orange Flashes in SRB Exhaust Plume**
(Camera E-208)

2.4 ONBOARD PHOTOGRAPHY OF THE ET (DTO 312)

2.4.1 Analysis of Handheld Photography of the ET *(Task #6)* *(S64-01-01 through 11)*

DTO-312 photography of the STS-64 external tank (after separation) was attempted with a Nikon camera with a 300 mm lens and a 2X extender (Method 3). Eleven exposures on magazine 01 were present. The external tank (ET) with the moon in the background was imaged on one frame (frame 03). The +Y/-Z side of the ET was visible. Approximately eleven divots were visible on the LH2 tank/intertank closeout flange (1). A divot was also visible on the LH2 tank acreage just aft of the intertank closeout flange (2). The sizes of these divots range from 5 to 6 inches in width and 8 to 12 inches in height. A white object (probably frozen hydrogen) was imaged on frames 04 and 05. The exposure of the ET was good. There was a slight blurring of the image (soft focus or motion smear). Timing data was present on the film. The pictures were taken over a one minute and forty four second time period from 22:37:14 UTC to 22:38:58 UTC. The picture of the ET was taken at 22:37:27 UTC.

Figure 2.4.1 Photograph of ET from Nikon Camera (Frame 03)

Video of the STS-64 external tank (after separation) was not acquired by the astronauts.

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

The umbilical well cameras were not flown on STS-64.

2.5 ON ORBIT EVENTS

An assessment was made of two items viewed on a downlink of video taken by the payload bay cameras during a survey of the vehicle condition. A damaged tile was reported by the crew on the port side OMS pod and a white piece of debris was noted on the starboard side of the vertical stabilizer.

Reviews of the video downlink during the SPIFEX experiment showed a slight discoloration of the felt reusable surface insulation (FRSI) blanket on the forward portion of the OMS pod at the 11 o'clock position as viewed from the crew cabin.

The debris seen near the vertical stabilizer is similar to debris seen on STS-35, STS-41, STS-43, and STS-54. The debris on previous missions had been attributed to ice formed during a water dump. The ice is believed to have shaken free on orbit due to payload bay door configuration changes or a payload release or capture. A video dub of the downlink from STS-41 was provided to the JSC mission evaluation room (MER) manager along with a verbal recount of the explanation for similar debris on previous missions. Images were selected from previous missions with similar debris and delivered to the MER.

2.5.1 SAFER Analysis *(Task #14)*

Measurements are planned in support of the Simplified Aid For EVA Rescue (SAFER) experiment flown on STS-64. Multiple camera views of the test sequence were obtained by the payload bay cameras. These views will be used to generate position and orientation of the astronaut in the cargo bay. By repeating the process on a series of images, the crew member's rotation and translation rates will be found. Analysis of the acquired data will take place over the next three months.

2.5.2 SPIFEX Analysis *(Task #15)*

Measurements are planned in support of the Shuttle Plume Impingement Flight EXperiment (SPIFEX) flown on STS-64. The single camera resectioning method (SCRM) is used in this analysis to determine a camera position in the coordinate system of a viewed object. SCRM numerically solves the lens equation and the coordinate transformation equations to determine a camera location and orientation. The error between the calculated feature projection points and the observed feature projection points on the image is the parameter which is minimized by the numerical solution. Six prioritized camera position measurements were generated from the SPIFEX video data acquired from the Position and Verification System (POVS) camera. Data from 105 different points will eventually be analyzed.

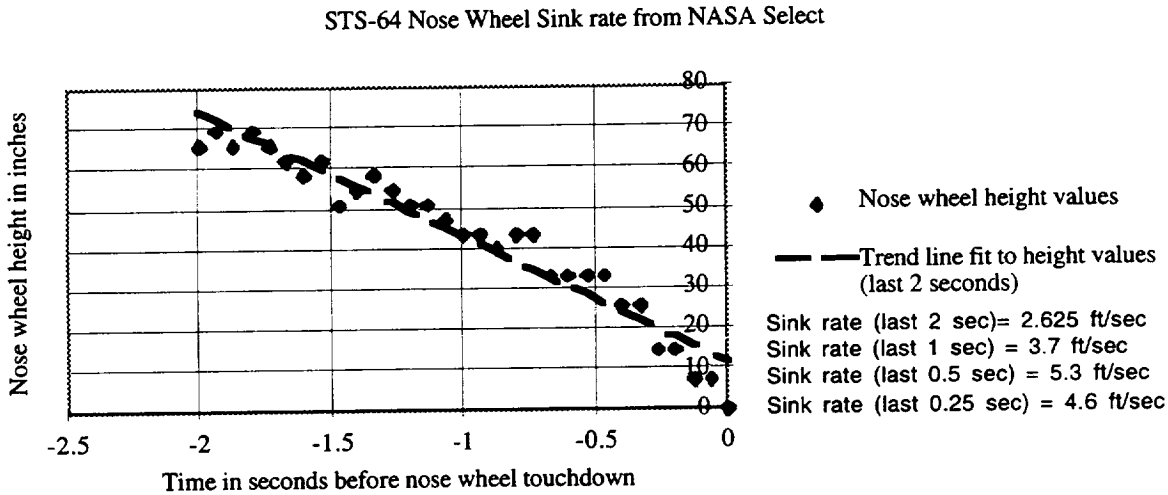


Figure 2.6.1.1 (b) Graph of Nose Gear Height Versus Time During Rollout

2.6.1.2 Landing Sink Rate Analysis Using Film

The measurement of the main gear and nose gear landing sink rate from film for the STS-64 mission had not been completed at the time of this report. A phototheodolite solution (multiple camera) of the Orbiter sink rate using the available film cameras with pointing information will be completed. This will be in contrast to the direct scaling solution (single camera) usually completed using both film and video products. Upon completion of this analysis, the data will be forwarded to the task requesters. Others interested in the results of this analysis should contact Brian Gastineau/HEI/713-483-5167 or Mark Holly/HEI/713-244-5106.

2.6.2 Drag Chute Performance *(Task #9)*
(Cameras E-1030 and E-1031)

The landing of Columbia at the end of mission STS-64 marked the seventeenth deployment of the Orbiter drag chute. The deployment of the drag chute appeared as expected. Event times were obtained from camera DTV-2.

Drag chute initiation	21:12:58.588 UTC
Pilot chute inflation	21:12:59.222 UTC
Bag release	21:13:00.090 UTC
Drag chute inflation in reefed position	21:13:01.091 UTC
Drag chute inflation in disreefed configuration	21:13:04.661 UTC
Drag chute release	21:13:31.121 UTC

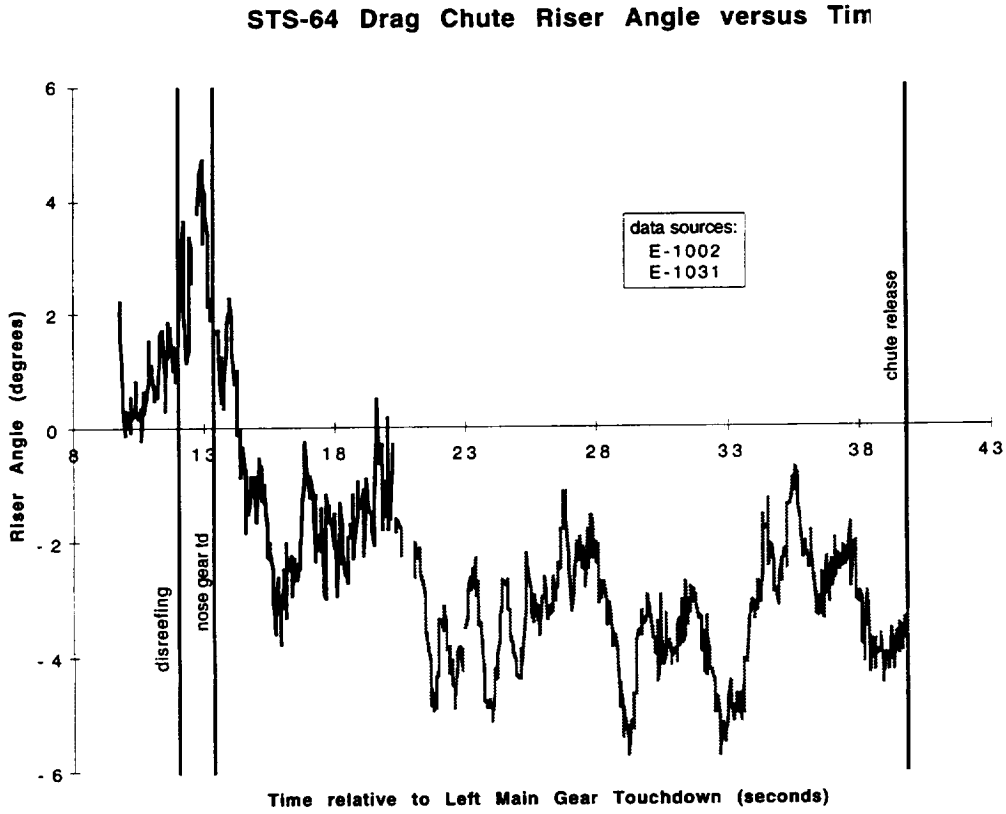


Figure 2.6.2 (b) Riser Angle Versus Time

Standard analysis of the drag chute angles as a function of time was performed using the views from the film cameras E-1002 and E-1031. This analysis is used to support the improvement of the aerodynamic math models currently in use. Figure 2.6.2b presents the measured heading angle versus time. Figure 2.6.2c presents the measured riser angle versus time. The maximum measured horizontal chute deflection (heading angle) was approximately 6.9 degrees to the starboard side of the vehicle. The vertical chute deflection (riser angle) ranged from -5.7 to +4.7 degrees relative to the Orbiter coordinate system.

2.6.3 Orbiter Height above Threshold *(Task #13)*

The height of the Orbiter above the threshold at landing has not yet been determined because of the late arrival of landing films. When the films arrive the height will be determined and the results will be sent to the task requesters.

2.7 OTHER NORMAL EVENTS

Other normal events observed include: normal SSME ignition sequence; ET twang prior to liftoff; frost on the ET vent louvers prior to liftoff; right and left inboard and outboard elevon vibration after SSME ignition and at liftoff; RCS paper debris after SSME ignition; multiple pieces of white debris (probably ice from the ET/Orbiter umbilicals) fell along the body flap after liftoff; ice and vapor from the GUCP area during ET GH2 umbilical vent arm retraction; vapors from the ET gaseous hydrogen umbilical disconnect during early liftoff; multiple pieces of dark debris in the exhaust cloud after liftoff; acoustic waves in the SRB exhaust plume after liftoff; vapor from both SRB stiffener

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

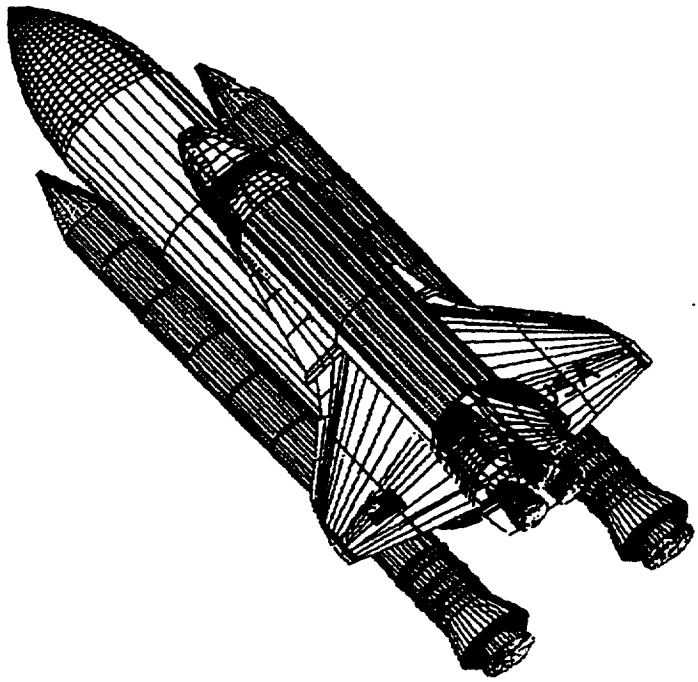
National Aeronautics and
Space Administration

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

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-64



STS-64 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

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

Camera data received at MSFC for STS-64

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	2	3	6
Tracking	0	15	9
Onboard	0	1	0
Totals	31	19	22
Total number of films and videos received:			72

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

a. Ground Camera Coverage:

All ground cameras performed as expected except for camera E-54 which had a short run but provided sufficient data. Tracking was erratic on camera E-222 which provided little data. All films had good exposures. Camera E-79 experienced a bad lens flare from the westerly sun angle and is not usable. The cloud coverage and the thick condensation collar which formed around the vehicle during ascent partially obscured the vehicle during ascent. Timing from several videos was not recorded at MSFC during the playbacks.

b. Onboard Camera Coverage:

Film from the astronaut 35mm hand-held camera was received at MSFC. The astronauts recorded one frame of the ET showing the +Y -Z quadrant prior to the ET going into darkness. Two frames of a frozen hydrogen particle were also recorded. There are no umbilical well cameras flown on the orbiter Discovery.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: ice/frost falling from the 17 disconnects during launch as shown in Figure 1, small pieces of debris such as butcher paper and paper hydrogen fire detectors falling aft during ascent, debris induced streaks/flares in the SSME plumes, loose SRB thermal curtain

tape, glowing debris particles exiting the SRM plumes and slag from the SRMs prior to and during SRB separation.

Figure 1. Ice from 17 inch disconnect area

b. ET TPS Assessment

There were several (approximately 11) divots located on the ET at the LH2 tank/intertank scarf joint. These divots are shown in Figure 2. The location of the divots is in the +Y -Z quadrant generally outside of the debris zone.

Figure 2. ET divots

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

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

HOLDDOWN POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	252:22:22:54.991
M-2	E-8	252:22:22:54.991
M-5	E-12	252:22:22:54.991
M-6	E-13	252:22:22:54.992

b. ET Tip Deflection:

ET tip deflection for this mission was not measured due to lack of photographic coverage. Camera E-79 experienced a lens flare from the westerly sun angle and operational television camera OTV-161 was not panned into a position to view the ET during SSME ignition and vehicle liftoff.

c. SRB Separation Time:

SRB separation time for STS-64 was 252:22:24:57.50 UTC as recorded by several tracking cameras.

APPENDIX C. ROCKWELL PHOTOGRAPHIC ANALYSIS SUMMARY

APPENDIX C

ENGINEERING PHOTOGRAPHIC ANALYSIS SUMMARY REPORT

STS-64

OCTOBER 5, 1994

PREPARED BY:

R. RAMON
MISSION OPERATIONS
ROCKWELL/DOWNEY

APPROVED BY:

N.L. GEISER
CAM, SHUTTLE INTEGRATION - DESIGN
ROCKWELL/DOWNEY

1.0 INTRODUCTION

The launch of Discovery (OV-103) on mission STS-64 occurred on September 9, 1994 at 3:22 p.m. PDT/GMT 252:22:22:54.982 from Launch Complex 39B (LC 39B), Kennedy Space Center (KSC). Landing occurred on September 20, 1994 at Edward's Air Force Base (EAFB) at 2:13 p.m. PDT/GMT 263:21:12.52. 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, uprange and downrange tracking sites, and SLF. Rockwell received launch films from 77 cameras (55 cine, 22 video) and landing films from 9 cameras (2 cine, 7 video) to support the STS-64 photographic evaluation effort.

2.0 ENGINEERING PHOTOGRAPHIC ANALYSIS SUMMARY

2.1 GENERAL OBSERVATIONS

Overall, the films showed STS-64 to be a clean flight. Several pieces of ice from the ET/Orbiter umbilical 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. Charring of the ET aft dome, recirculation and brightening of the SRB plumes were normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal.

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Mission Elapsed Time (MET), as is normal. All blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH2 vent line carrier dropped normally and latched securely with a slight rebound. No anomalies were identified with the ET/ORB LH2 umbilical hydrogen dispersal system hardware.

2.0 SUMMARY OF SIGNIFICANT EVENTS OBSERVED

2.2.1 MLP AND LIFTOFF EVENTS

2.2.1.1 Orange Vapor (Possibly Free - burning Hydrogen)

On cameras OTV-163, OTV-171, E-76 and E-77, Orange Vapor (possibly free burning hydrogen) was noted below the SSME bells just prior to ignition. This vapor has been observed on previous flights and no follow-on work is scheduled.

2.2.4 LANDING EVENTS

The landing of STS-64 occurred on Runway 04 at Edward's Air Force base. Good video and film coverage were obtained. Main landing gear touchdown occurred at 263:21:12:52 GMT and nose landing gear touchdown occurred at 263:21:13:03 GMT with wheel stop occurring at 263:21:13:54 GMT.

2.2.4.1 Drag Chute System

The flight marked the seventeenth use of the Orbiter drag chute. The drag parachute system performed as expected. All sequenced events occurred as expected, and no hardware anomalies were observed. All drag chute hardware was recovered and post-landing inspection showed no sign of abnormal operation.

2.2.4.2 Main landing gear door thermal barrier missing

During the post-landing inspection it was noted that an 18 inch section of main landing gear door thermal barrier, including carrier panel, were missing from the aft inboard area of both the right and left gear wells. These two items fell from the vehicle during gear deployment and were found approximately 4000 feet from the runway 04 threshold.

2.2.4.3 Dome Mounted Heat Shield thermal blanket damage

During the post-landing walk around it was noted that the Dome Mounted Heat Shield (DMHS) closeout blanket was slightly frayed at the 4 to 6 O'clock position of SSME #1.

2.2.5 OTHER NORMAL EVENTS

The following events have been reported on previous missions and observed on STS-64. These are not of major concern, and include: Ice debris falling from the ET/Orbiter Umbilical disconnect area, Debris (Insta-foam, water trough) in the holddown post area and MLP, Charring of the ET aft dome, ET aft dome outgassing after liftoff, RCS Paper debris, Recirculation or expansion of burning gasses at the aft end of the SLV prior to SRB separation, Slight TPS erosion on the base heat shield during SSME start-up, Twang motion, Body flap motion during the maximum dynamic pressure (MAX-Q) region which appeared to have an amplitude and frequency similar to those of previous missions, Linear optical distortion, possibly caused by shock waves or ambient meteorological conditions near the vehicle, during ascent, Slag in SRB plume after separation, Vapor from the SRB stiffener rings after liftoff, and Condensation on the Orbiter forward fuselage, ET nose and SRB frustums during ascent.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1994	Final 8-22 September 1994

4. TITLE AND SUBTITLE

Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-64

5. FUNDING NUMBERS

6. AUTHOR(S)

Gregory N. Katnik
Barry C. Bowen
J. Bradley Davis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NASA
External Tank Mechanical Systems
Mail Code: TV-MSD-7
Kennedy Space Center, Florida 32899

8. PERFORMING ORGANIZATION REPORT NUMBER

TM 109206

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Publicly Available
Unclassified - Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-64. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-64, and the resulting effect on the Space Shuttle Program.

14. SUBJECT TERMS

STS-64 Thermal Protection System (TPS)
Ice Debris Photographic Analysis

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited