# Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-71

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



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# DEBRIS/ICE/TPS ASSESSMENT
# AND
# INTEGRATED PHOTOGRAPHIC ANALYSIS
# OF
# SHUTTLE MISSION STS-71

**27 June 1995**

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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 Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

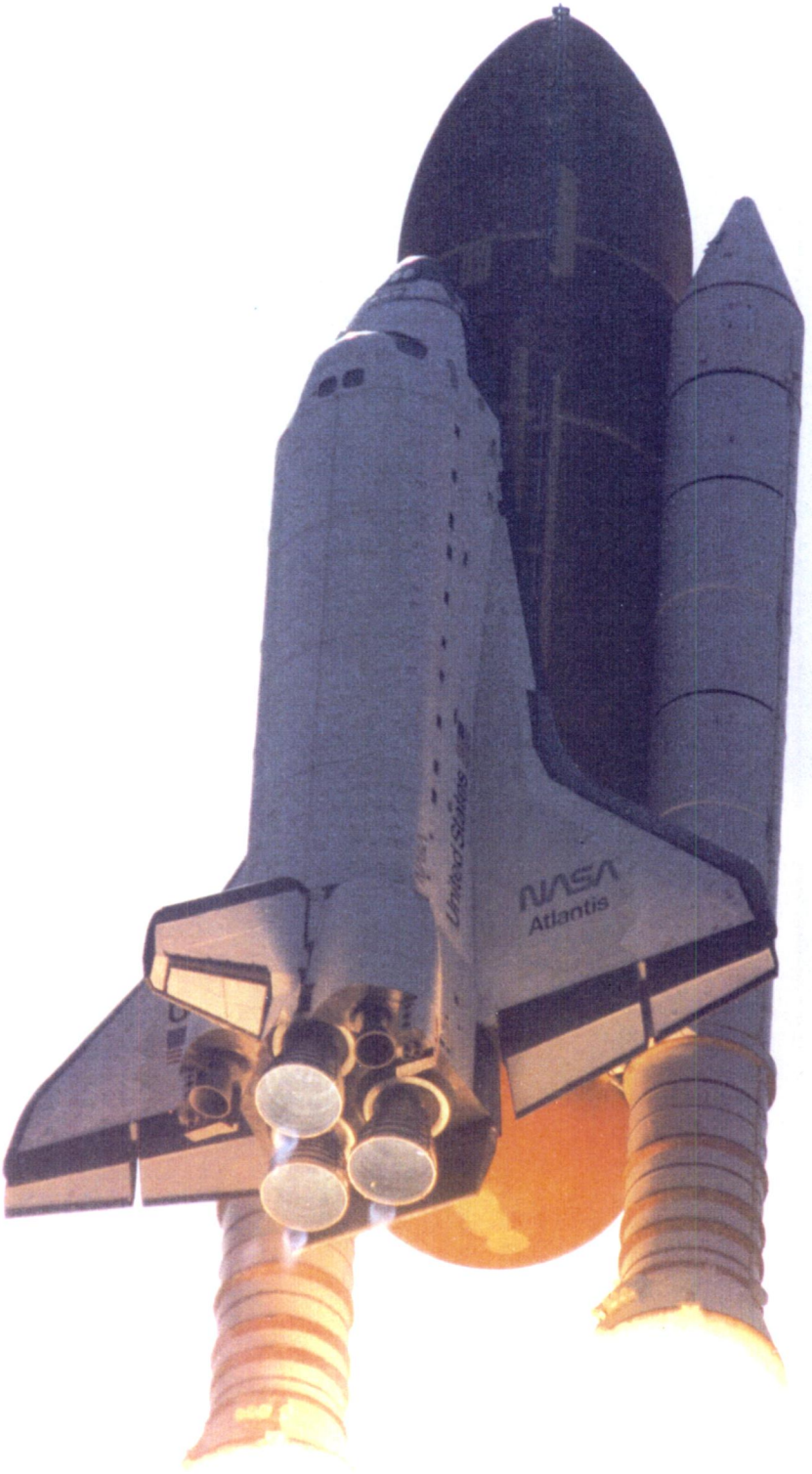


**Photo 1 : Launch of Shuttle Mission STS-71**

# 1.0 SUMMARY

A pre-launch debris inspection of the pad and Shuttle vehicle was performed on 22 June 1995. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-104 Atlantis (14th flight), ET-70 (LWT 63), and BI-072 SRB's. There were no vehicle or facility anomalies.

A launch attempt was scrubbed 23 June 1995 prior to cryoload due to the prediction of unacceptable weather. The vehicle was cryoloaded for flight on 24 June 1995. However, that launch attempt was scrubbed at T-9 minutes due to inclement weather at the launch site. Post drain inspection revealed ET topcoat was loose/missing from the lower half of the -Y alignment grid and around the vent louver. The redesigned bipod jack pad closeouts were intact and flush with adjacent foam.

The vehicle was cryoloaded again on 27 June 1995. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. As expected, there was no acreage ice or frost given the ambient weather conditions at this time of year. There were no protuberance icing conditions outside of the established data base.

The Final Inspection Team noted paper covers on Orbiter RCS thrusters L1L and L3L were wet. The covers on R2U and R4D were tinted green indicating a small internal vapor leak. More than usual ice/frost formations and venting vapors were present around the ET umbilical carrier plate. Liquid air drips seemed to originate from the ice suppression shroud area during cryoload, but stopped after ice and frost accumulated to form an ice insulation. The leak detectors gave no indication of an internal leak.

After the 03:32:19 p.m. (local) launch on 27 June 1995, a debris walk down of Pad 39A 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. All the T-0 umbilicals operated properly. Topcoat from the External Tank nose cone adhered to both GOX seals. (The seals stuck momentarily to the ET nose cone during vent hood retraction). There was no visible damage to the GUCP or QD that may have contributed to the heavier-than-usual formation of ice/frost along with venting vapors and liquid air drops observed during cryoload. The seals were inspected closely during GUCP disassembly. All mechanical interfaces and bolts were checked. No cause for the liquid air drops was found. Overall, damage to the launch pad was minimal.

A total of 124 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission. SSME ignition appeared normal. However, the Mach diamond on SSME #1 formed before the Mach diamond appeared on SSME #2. Oxidizer vapors exited aft RCS thruster R2U as the paper cover ruptured during SSME ignition. This thruster had exhibited signs of a very small leak prior to launch. An unusually bright flash from SRB ignition caused light to be reflected off of the RH SRB aft booster and ET aft dome at T-0. A rigid object, approximately 7-inches long by 2-inches wide by 1/2-inch thick, was ejected out of the LH SRB exhaust hole near HDP #7 shortly after T-0. The object, which may have been a piece of brick from the flame trench, moved away from the vehicle. No contact with flight hardware was observed. Grease or EPON shim epoxy was visible burning on the HDP #2 shoe at T+7 seconds MET. A similar event occurred on the STS-63 launch. Localized flow condensation collars on various parts of the vehicle and wing tip contrails were visible during ascent as expected for a humid summer launch.

Orbiter umbilical camera films showed nominal separation of SRB's from the External Tank and normal separation of the ET from the Orbiter. Eight stringer head divots, ranging in length from 12 to 24 inches, were observed on the intertank. The loss of foam from these intertank divots contributed to the 149 (greater than average) number of hits on the Orbiter lower surface. This type of divot had been the subject of an IFA previously. Stringer head cleaning and worker walk load procedures were modified as a result of the IFA effective ET-74. The redesigned bipod jack pad closeouts were intact. The LO2 ET/ORB umbilical sustained TPS damage at both inboard and outboard forward corners. Lightning contact strips across the forward part of the umbilical and at the 8 o'clock position were missing. Loss of lightning contact strips was also the subject of a previous IFA. A modification to the design will attach the lightning contact strips with fasteners.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The number of MSA-2 debonds on the RH frustum was average but somewhat higher than average on the LH frustum. Hypalon paint was blistered/missing from areas where BTA closeouts had been applied on the frustums, forward skirts, and aft skirts. The LH frustum was missing one 2-inch diameter piece of TPS (divot) near the XB-395 ring frame between the +Y/+Z axes. The exposed substrate appeared darkened. Laboratory analysis showed the divot was caused by a debond of the MSA-2 from the PR-1422. The divot occurred after BSM firing (absence of sooting) but sometime during re-entry (heating effects).

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-104 was conducted 7 July 1995 on SLF runway 15 at the Kennedy Space Center. The Orbiter TPS sustained a total of 164 hits, of which 25 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of hits and the number of hits 1-inch or larger was greater than average. The Orbiter lower surface sustained a total of 149 hits, of which 24 had a major dimension of 1-inch or larger. The loss of foam insulation from the ET intertank during flight contributed to the number of tile damage sites. Tile damage on the window perimeter tiles was significantly less than usual. A concerted effort had been made to minimize the RTV used for attaching paper covers to forward RCS thrusters.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the facility environment, SRB BSM exhaust, Orbiter RCS nozzle cover adhesive, Orbiter TPS, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of the noted materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of nine Post Launch Anomalies, but no In-Flight Anomalies (IFA's), were observed during the STS-71 mission assessment.

## 2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 22 June 1995 at 1600 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.

| | |
|---|---|
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| G. Katnik | NASA - KSC Shuttle Ice/Debris Systems |
| B. Davis | NASA - KSC Digital Imaging Systems |
| R. Speece | NASA - KSC Lead, Thermal Protection Systems |
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| Z. Byrns | NASA - KSC Level II Integration |
| W. Atkinson | Rockwell LSS Systems Integration |
| R. Haskell | THIO - LSS SRM Processing |
| S. Otto | LMSO - LSS ET Processing |
| K. Ely | LMSO - LSS ET Processing |
| D. Maxwell | LMSO - SPC Safety |

## 3.0 LAUNCH

STS-71 was launched at 27:19:32:19.005 GMT (3:32:19 p.m. local) on 27 June 1995.

### 3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 22 June 1995, from 1700 to 1815 hours. The detailed walkdown of Pad 39A and MLP-3 also included the primary flight elements OV-104 Atlantis (14th flight), ET-70 (LWT 63), and BI-072 SRB's. There were no vehicle or facility anomalies.

### 3.2 WEATHER SCRUB

A launch attempt was scrubbed prior to cryoload due to the prediction of unacceptable weather. The vehicle was cryloaded for flight on 24 June 1995. The Final Inspection was performed from 1045 to 1210 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. As expected, there was no acreage ice or frost given the ambient weather conditions at this time of year. There were no protuberance icing conditions outside of the established data base.

The only anomaly on the Orbiter consisted of a visible liquid level line (approximately 25 percent of the nozzle diameter) on aft RCS thruster R3R. This water intrusion was the result of recent heavy rain on the pad. Paper covers on the L4D and R2U thrusters were tinted green, which is indicative of a slight internal vapor leak.

The launch was scrubbed at T-9 minutes due to inclement weather at the launch site. Pad access was not available after the scrub due to a ECS problem. The post drain inspection of the vehicle was performed on 25 June 1995.

Topcoat was loose/missing from the lower half of the -Y alignment grid and around the vent louver. The redesigned bipod jack pad closeouts were intact and flush with adjacent foam.

### 3.3 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 27 June 1995 from 0920 to 1050 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. As expected, there was no acreage ice or frost given the ambient weather conditions at this time of year. There were no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle.

### 3.4 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The paper covers on RCS thrusters L1L and L3L were wet. The covers on R2U and R4D were tinted green indicating a small internal vapor leak. Typical ice/frost accumulations and condensate were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

## 3.5 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the fixed STI radiometers were not available for this flight due to facility problems. Temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 78-90 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by THIO was 79 degrees F, which was within the required range of 44-86 degrees F.

## 3.6 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 light condensate, but no ice or frost accumulations, on the LO2 tank. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies. More than usual ice/frost formations and venting vapors were present around the ET umbilical carrier plate. Liquid air drips seemed to originate from the ice suppression shroud area during cryoload, but stopped after ice and frost accumulated to form an ice insulation. The leak detectors gave no indication of an internal leak.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost accumulations, were present on the acreage.

There were no anomalies on the redesigned bipod jack pad closeouts. A crack, 6-inches long by 1/4-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.

Typical 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 were present on the pyro canister and plate gap purge vents. Ice/frost had formed on the aft pyro canister closeout bondline. 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 four OTV recorded items.

## 3.7 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. Although no leaks were detected by sensors, more than usual vapors and ice/frost formations were present on the Ground Umbilical Carrier Plate (GUCP). Liquid air dripped from the ice suppression shroud area until a short time into stable replenish.

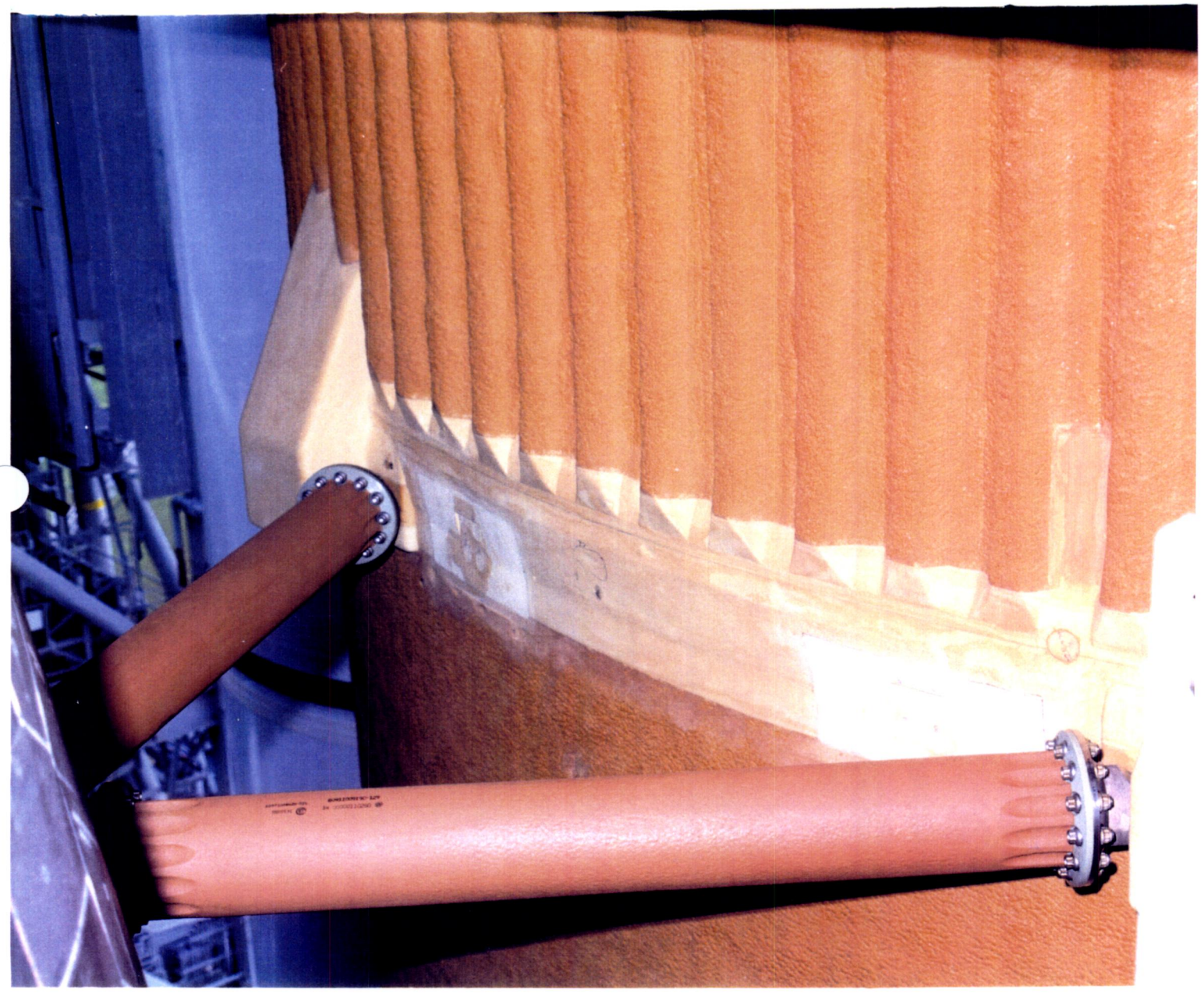


**Photo 2 : Redesigned Bipod Jack Pad Closeouts**

First flight of the new jack pad closeouts on ET-70

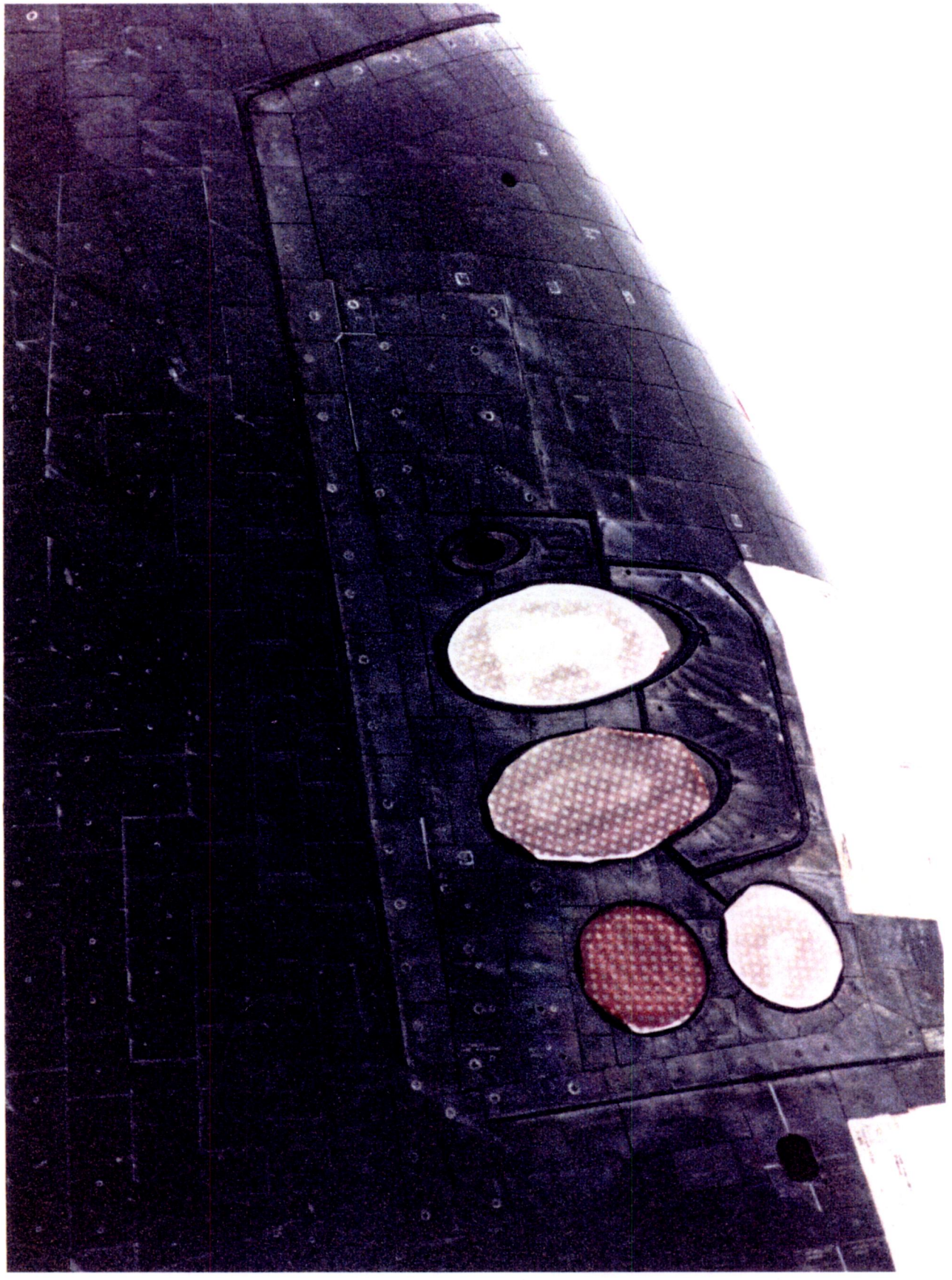


**Photo 3 : Forward RCS Thruster Covers**

View of wet FRCS thruster paper covers during first launch attempt. Note difference between dark F3L cover, indicative of a slight internal vapor leak, and the lighter F3D cover wetted by recent rainfall.

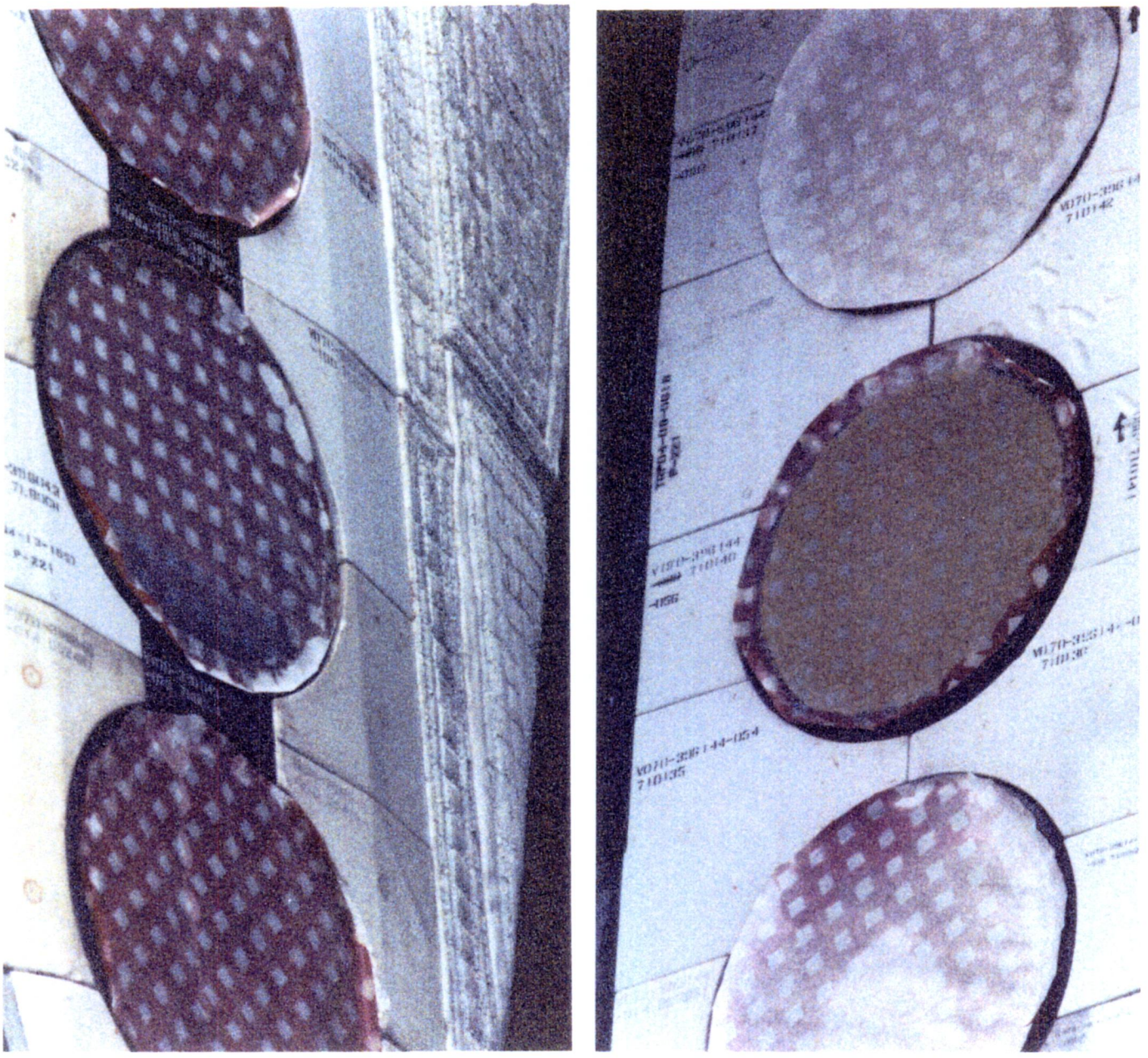


**Photo 4 : Aft RCS Thruster Covers**

Liquid, most likely water from recent heavy rain on the pad, was visible behind aft RCS thruster R3R. Paper covers on the L4D and R2U thrusters were tinted green, which is indicative of a slight vapor leak. These conditions were noted during the first launch attempt.

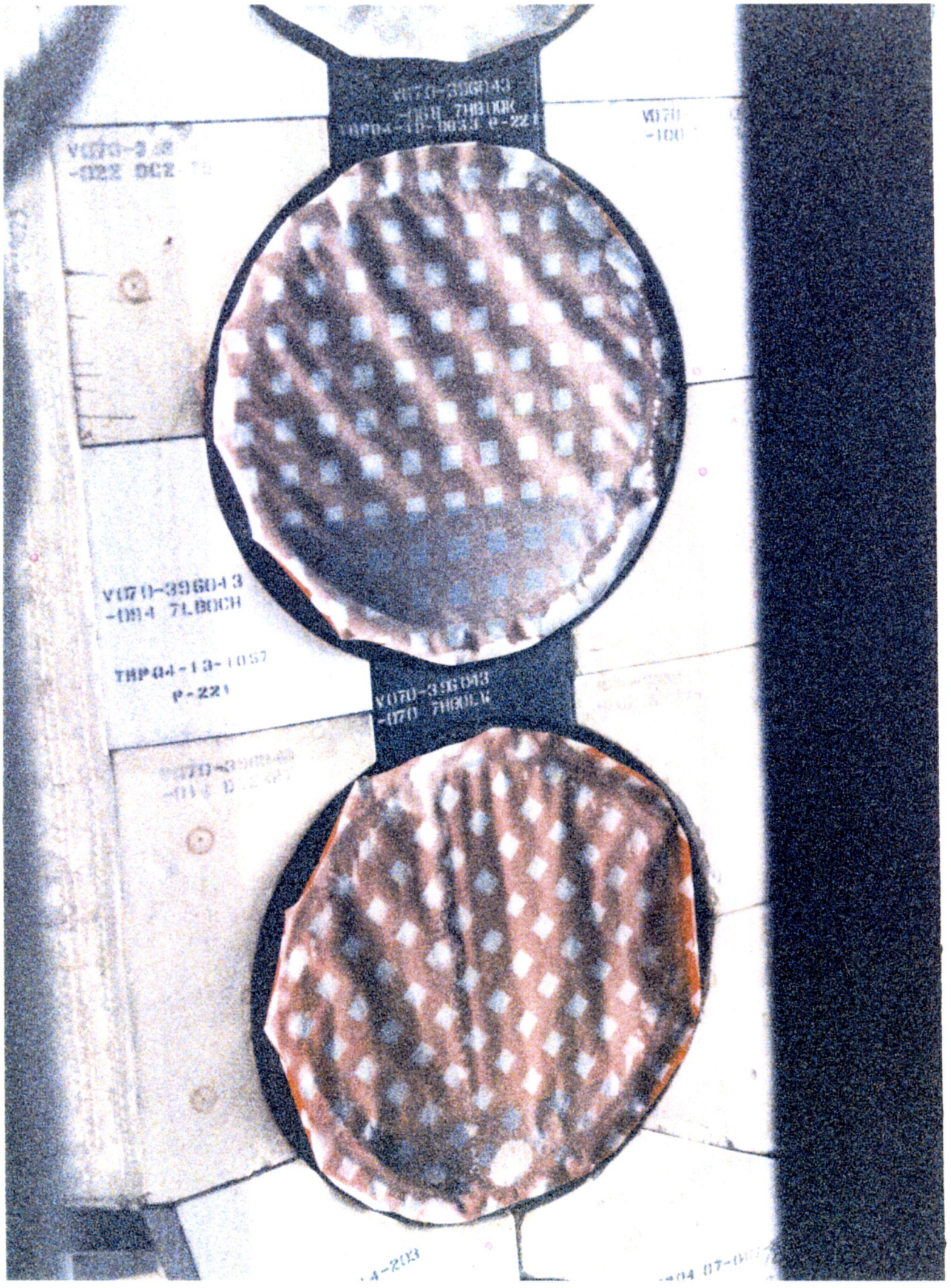



**Photo 5 : Post Drain Inspection of RCS Covers**

Close-in view of rain water trapped behind aft RCS paper covers.
Water was removed and new covers installed during scrub turnaround.

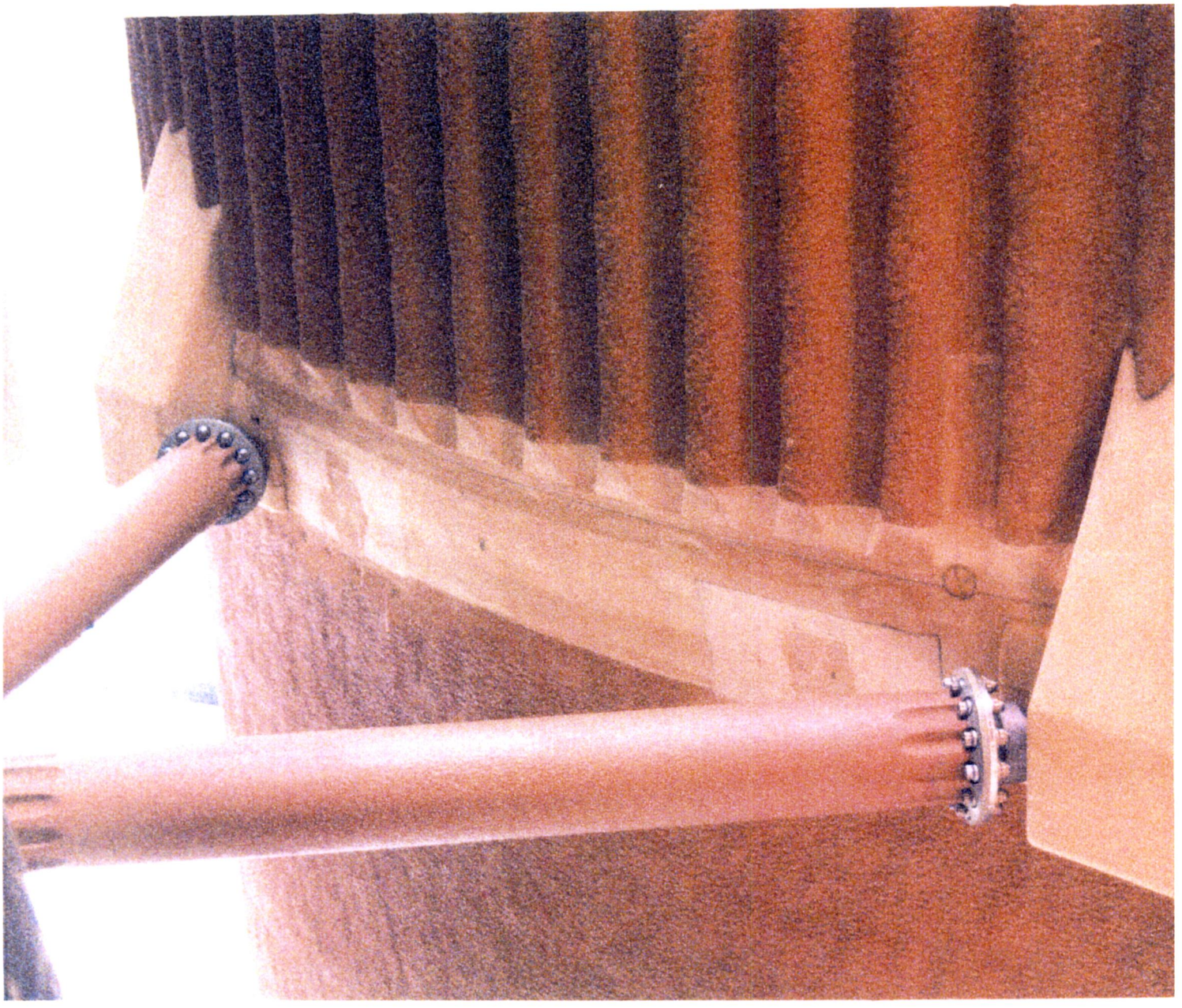


**Photo 6 : Post Drain Condition of Jack Pad Closeouts**

The redesigned bipod jack pad closeouts were intact and flush with adjacent closeout foam

**Photo 7 : Post Drain Condition of ET Nose Cone Area**

Topcoat was missing from the lower half of the alignment grid and peeled around the vent louver

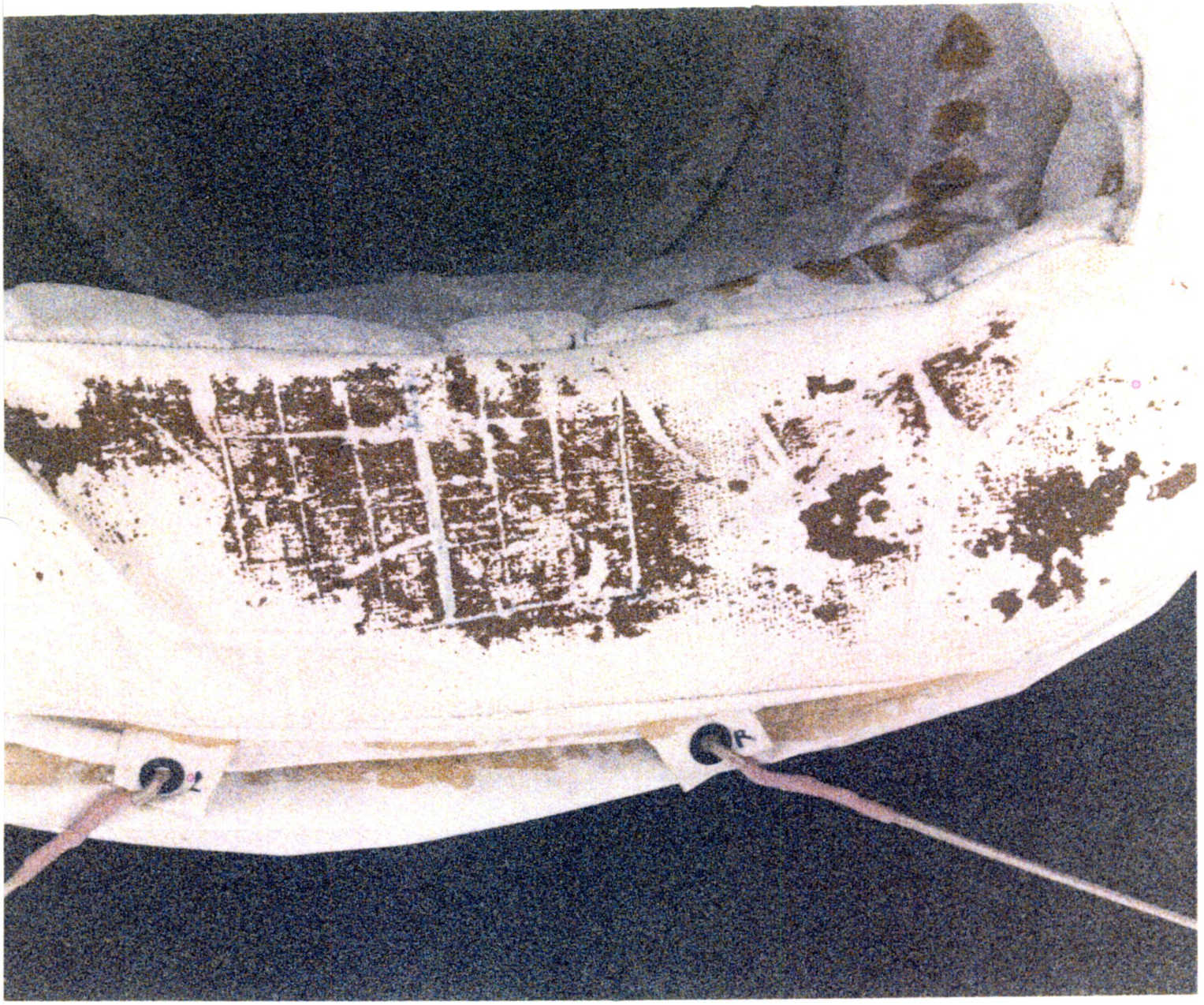


**Photo 8 : Topcoat Adhered to -Y GOX Vent Seal**

Topcoat adhered to GOX vent seals and was subsequently pulled up from the ET nose cone footprint area during GOX hood retraction. Post drain inspection found the missing topcoat, but no TPS, adhering to both GOX vent seals.

**Photo 9 : ET Nose Cone/Footprint Area**

Loose topcoat had been removed during the scrub turnaround. Missing topcoat from the nose cone footprint area and around the louver was a condition accepted for flight.

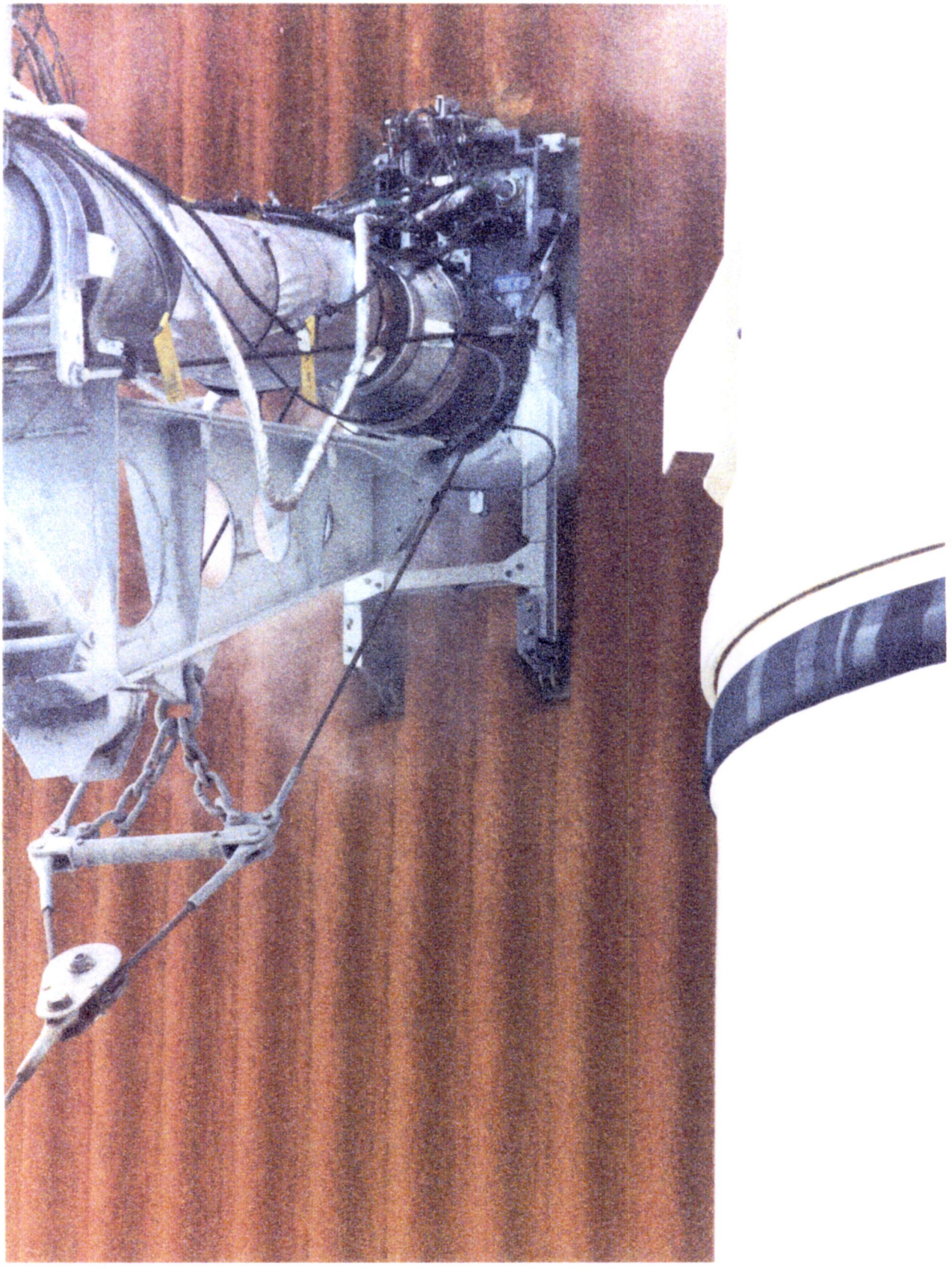


**Photo 10: Liquid Air/Ice Formations on GUCP**

More than usual ice/frost formations and venting vapors were present around the ET umbilical carrier plate. Liquid air drips seemed to originate from the ice suppression shroud area during cryoload, but stopped after ice and frost accumulated to form an ice insulation. The leak detectors gave no indication of an internal leak.

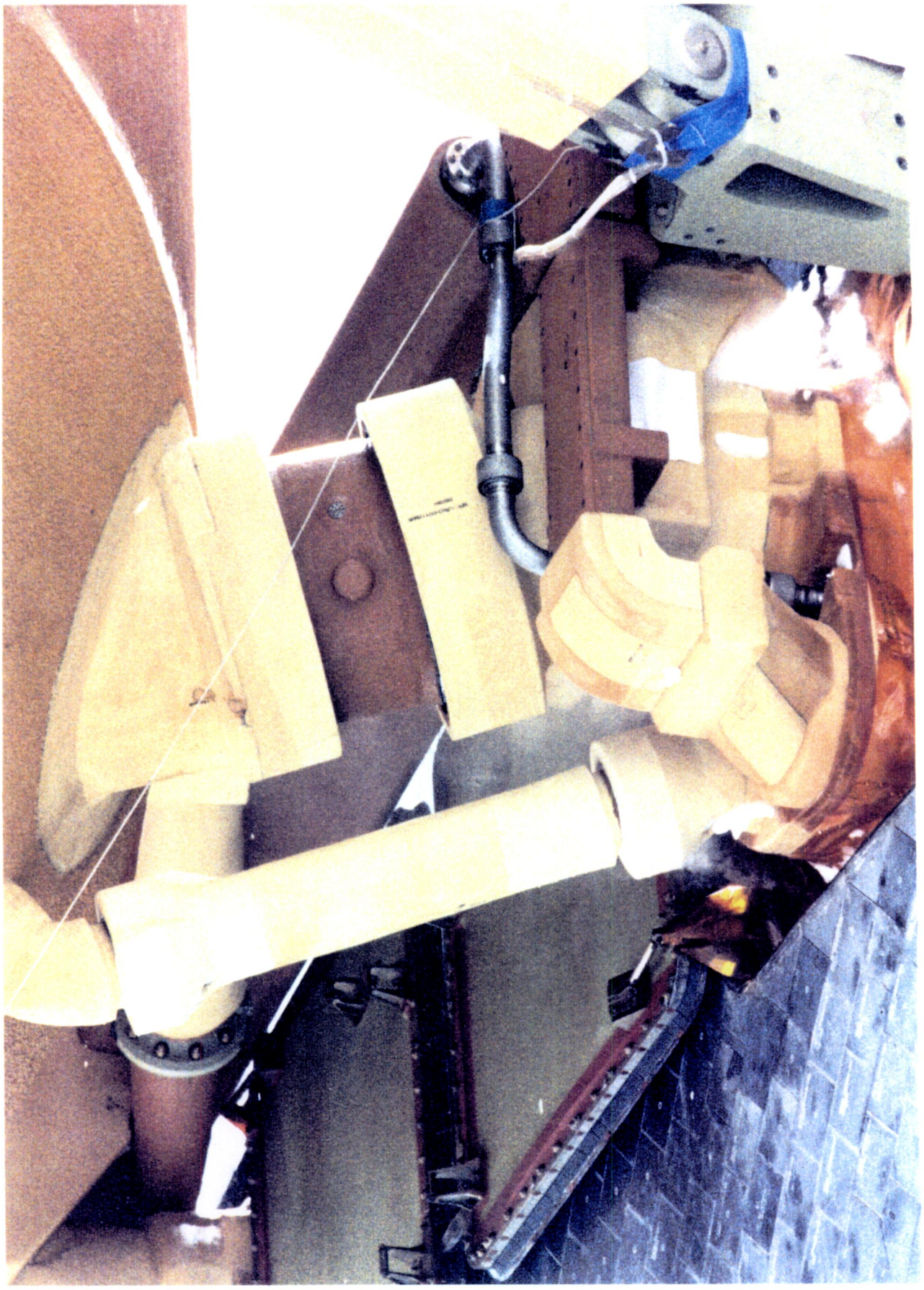


**Photo 11: LH2 ET/ORB Umbilical**

Less than usual amounts of ice/frost accumulated on the LH2 umbilical during cryoload

## 4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS and RSS was conducted on 27 June 1995 from Launch + 1.5 to 3.5 hours.

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 hangup 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 minimal. Vertical 2-inch long cracks were visible in the HDP #3 and HDP #7 sacrificial plates. A 2-foot long crack in the HDP #4 sacrificial plate was offset by a half inch. However, the size of the cracks had not changed significantly from the prior-to-launch measurements. Minor damage to the SRB aft skirt purge lines and T-0 umbilicals was similar to previous launches.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent hood appeared undamaged. Topcoat from the External Tank nose cone adhered to the lower areas of both +Y and -Y GOX seals. The seals stuck momentarily to the ET nose cone during GOX vent hood retraction at T-2:30 minutes.

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

There was no visible damage to the GUCP or QD that may have contributed to the heavier-than-usual formation of ice/frost along with venting vapors and liquid air drops observed during cryo load. The seals were inspected closely during GUCP disassembly. All mechanical interfaces and bolts were checked. No cause for the liquid air drops was found.

The RSS cable separated properly from the new connector (with the 90 degree elbow).

Typical pad damage included:

Two inch diameter conduit cap on the FSS 95 foot level near the MLP crossover

Three foot long by 3/8-inch diameter rod on FSS 135 foot level grating

Loose electrical connectors on FSS 155 and 215 foot levels

Missing ECS line cover on FSS 215 foot level

Post launch pad inspection anomalies are listed in Section 9.

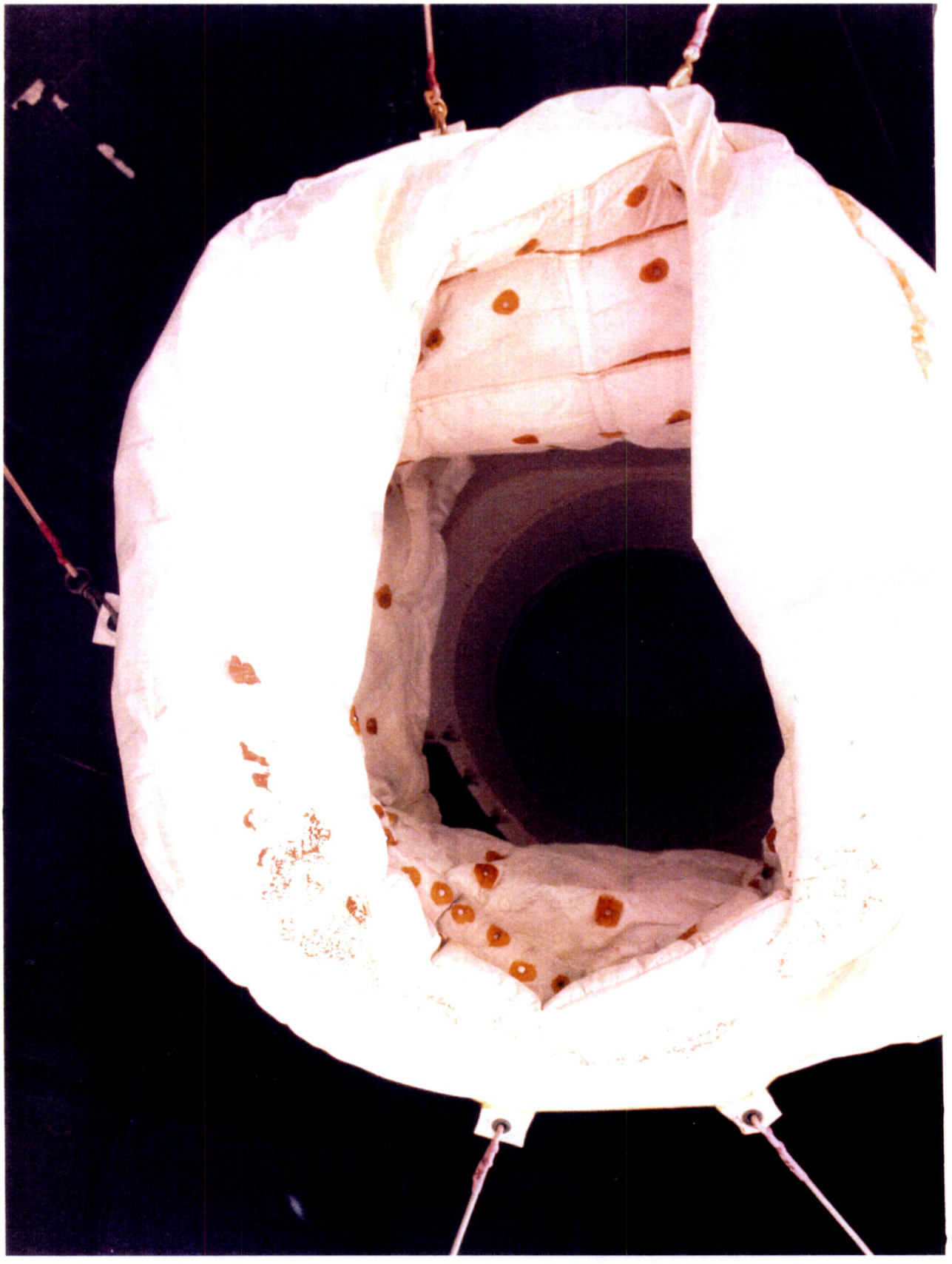


**Photo 12: Nose Cone Topcoat Adhered to GOX Vent Seal**

The seals stuck momentarily to the ET nose cone during GOX vent hood retraction at T-2:30 minutes. Nose cone foam insulation was not damaged.

**Photo 13: Holddown Post Sacrificial Plate Crack**

A 2-foot long crack in the HDP #4 sacrificial plate was offset by a half inch.

## 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 IFA's 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-nine 16mm films, nineteen 35mm films, three 70mm films, and thirty-seven videos, were reviewed starting on launch day.

Both northeast and southwest GOX vent seals stuck momentarily to the External Tank nosecone topcoat during seal deflation/retraction at T-2:30. Numerous small pieces of topcoat were pulled loose from both footprint areas and adhered to the seals. This condition was acceptable for launch. Residual GOX vapors vented from the frost-coated ET northeast louver. MPS vibration caused four pieces of frost to fall away from the louver. The External Tank "twanged" approximately 32 inches during SSME ignition (E-79; OTV 060, 061).

SSME ignition appeared normal (OTV 051, 070, 071). However, the Mach diamond on SSME #1 formed before the Mach diamond appeared on SSME #2. Free burning hydrogen had drifted under the body flap and upward to the base heat shield/OMS pods during start-up (OTV 063, 070, 071). A flare occurred in the SSME #3 plume at GMT 19:32:16.812 during startup (E-2, -3). Three flares were visible in the SSME #1 plume prior to liftoff (E-52).

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.

Tile surface coating material was missing from as many as seven places on the +Z side of the body flap between the outboard edge and the SSME #3 position (E-76). Small pieces of tile surface coating material were also lost from 4 places on the base heat shield, 5 places on RH OMS pod tiles, and 1 place on the body flap +Z side between SSME #2 and #3 (E-17, -18, -19, -20).

Oxidizer vapors exited the R2U ARCS thruster as the paper cover ruptured during SSME ignition. This thruster had exhibited signs of a very small leak prior to launch (E-2, -19).

Vapors exiting the -Y ET/SRB strut/cable tray drain hole was an expected occurrence due to the humid atmospheric conditions at the time of launch (E-34, -35).

Left inboard and outboard elevons exhibited very noticeable movement during SSME ignition and liftoff (E-31).

Ice was shaken loose from the LO2 feeline upper bellows, but no impacts to flight hardware were observed (E-65).

A thin, 2-inch long by 1-inch wide object, most likely a piece of facility scale/paint, fell downward past the E-3 camera lens at GMT 19:32:14.748. At GMT 19:32:15.815, a lightweight object, possibly an RCS paper cover or piece of purge barrier from the LH2 TSM, appeared near the SSME #2 nozzle from behind the LH2 TSM and was pulled into the SSME exhaust hole by aspiration (E-3). Neither object interferred with flight hardware.

An unusually bright flash from SRB ignition caused light to be reflected off of the RH SRB aft booster and ET aft dome at GMT 19:32:19.091 - 32:19.158 (OTV 048). The reflected light on the ET aft dome is visible to a lesser extent on OTV 054 at GMT 19:32:19.136; film items E-1 and E-4.

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 (E-7 thru E-14).

A rigid object, approximately 7-inches long by 2-inches wide by 1/2-inch thick, was ejected out of the LH SRB exhaust hole near HDP #7 at GMT 19:32:20.186. The object, which may have been a piece of brick from the flame trench, moved away from the vehicle. No contact with flight hardware was observed (E-11).

Although an expected event, more than usual amounts of SRB throat plug and sound suppression water trough material exited the SRB exhaust holes at T-0 (E-1, -4, -15, -16). A piece of SRB throat plug moving upward passed the ET aft dome and then fell straight downward at GMT 19:32:19.536 (OTV 009). The particle near HDP #1 in OTV 063 at GMT 19:32:19.169 may be the same piece of throat plug material.

GUCP disconnect from the ET was nominal. No foam was torn loose during retraction. A "V"-shaped ice line was present under the RSS coax cable connector and most likely formed as a result of the liquid air dripping condition during cryoload. The RSS coax cable pulled away properly from the redesigned connector (with the 90 degree elbow). GH2 vent line retraction and latch were normal. Pieces of ice shook loose from the GUCP and fell aft without contacting flight hardward (E-41, -50, -60). A dark object on the ET acreage TPS near the SRB forward field joint was believed to be an insect (E-33).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 050).

The paper cover on the FRCS F3L thruster ripped shortly after liftoff (E-40, -59).

Grease or EPON shim epoxy was visible burning on the HDP #2 shoe at T+7 seconds MET. A similar event occurred on the STS-63 launch.

An object passing the Orbiter right wing tip and eventually lost in the glare from the LH SRB exhaust plume at GMT 19:32:22.209 was believed to be an insect or bird near the camera lens (TV-4A). The object was first visible against blue sky in the right field-of-view near the RH SRB.

A stream of vapor, believed to be a contrail from the left wing tip, appeared to brighten by backlighting from the sun at GMT 19:32:38 (TV-4A). A wing tip contrail was also visible in TV-21 at GMT 19:32:39.

A flash occurred in the SSME plume at GMT 19:33:01.615. Other possible flashes occurred at GMT 19:33:04.452 and 19:33:04.685 (TV-4A; E-223).

Localized flow condensation collars on various parts of the vehicle and wing tip contrails were visible during ascent as expected for a humid summer launch (E-213, -220, -222, -224, TV-4A).

Body flap movement (amplitude and frequency) was similar to previous flights (E-212).

Exhaust plume recirculation, ET aft dome charring, and SRB separation appeared nominal. Numerous pieces of slag dropped out of the SRB plume during and after separation (E-204, -205, 207, -208, -218, -220, -223).

**Photo 14: Vapors from Aft RCS Thruster**

Oxidizer vapors exited aft RCS thruster R2U as the paper cover ruptured during SSME ignition. This thruster had exhibited signs of a very small leak prior to launch.

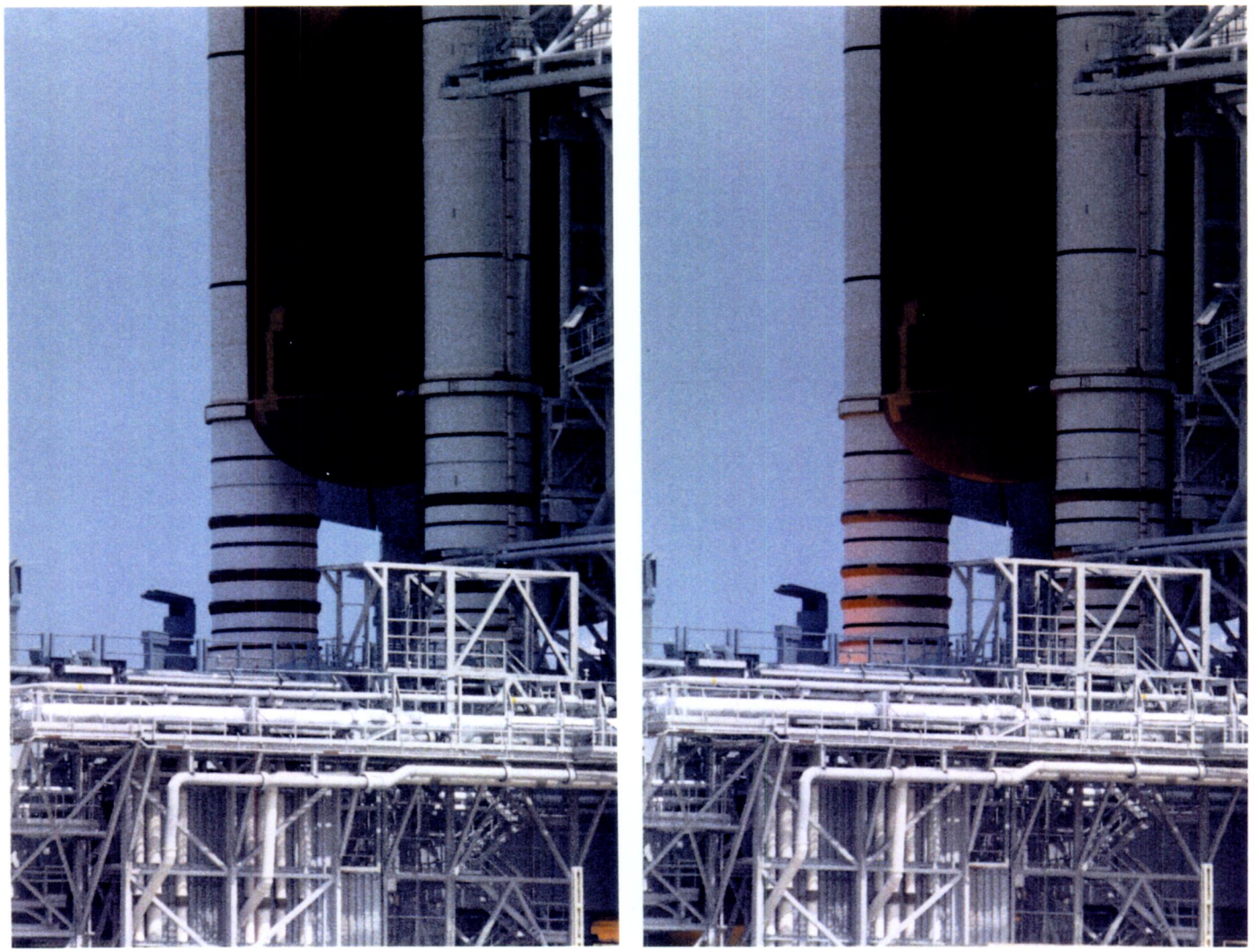


**Photo 15: Flash on RH SRB and ET Aft Dome**

A flash from SRB ignition caused light to be reflected off of the RH SRB aft booster and ET aft dome

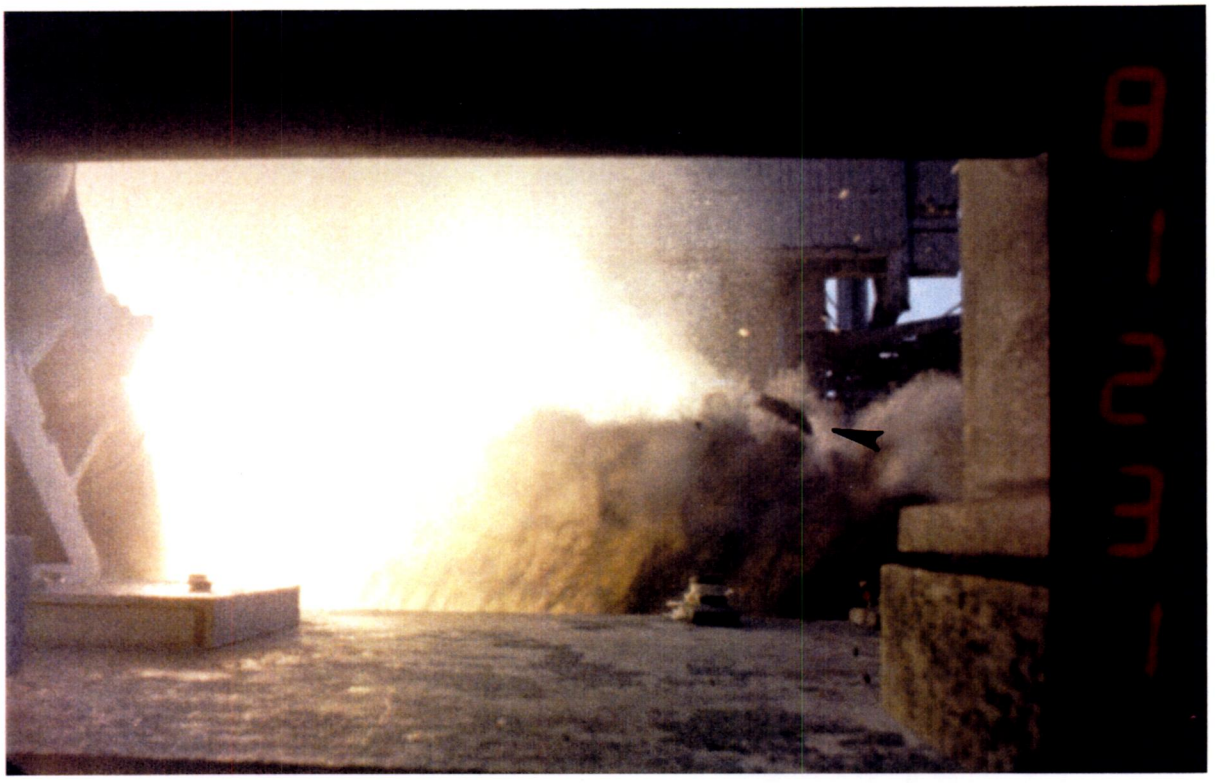


**Photo 16: Debris Ejected from SRB Exhaust Hole**

A rigid object, approximately 7-inches long by 2-inches wide by 1/2-inch thick, was ejected out of the LH SRB exhaust hole near HDP #7 at T-0. The object, which may have been a piece of brick from the flame trench, moved away from the vehicle. The flight hardware was not contacted.

## 5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-104 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. Data was obtained from all three cameras. Hand held photography by the flight crew was omitted for this mission.

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

SRB separation from the External Tank was nominal. More than usual, but small, pieces of foam fell past the camera lens.

ET-70 separation from the Orbiter was nominal. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, PAL ramps, LO2 feed line, and aft dome. A string-like piece of white RTV moved past the camera lens during umbilical separation.

Eight stringer head divots, ranging in length from 12 to 24 inches, were observed on the intertank acreage: two divots forward of the bipods at station XT-1080; one divot forward of the bipods on centerline at station XT-960; one divot forward of the LO2 feedline fairing at station XT-860; one divot forward and outboard of the -Y bipod spindle housing at station XT-1080; and three divots between the LO2 feedline and the +Y EB fitting at station XT-1080. The loss of foam from these intertank divots contributed to the 149 (greater than average) number of hits on the Orbiter lower surface. This type of divot had been the subject of an IFA previously. Stringer head cleaning and worker walk load procedures were modified as a result of the IFA effective ET-74.

The redesigned bipod jack pad closeouts were intact.

The LH2 tank acreage was generally in good condition with the exception of one shallow divot at the flange closeout interface aft of the -Y bipod spindle housing closeout. One 5-inch diameter divot near the LO2 feedline at station XT-1377 and one 5-inch divot between the LO2 feedline and the pressurization line support at station XT-1377 appeared to expose substrate by showing primer. Numerous shallow "popcorn" type divots occurred forward of the crossbeam.

LO2 feedline flange closeouts, both thrust strut flange closeouts, and the TPS on several pressurization line supports exhibited minor erosion. Ice was still present in the LO2 feedline lower bellows.

The LH2 ET/ORB umbilical appeared to be in good condition with little or no TPS damage. Foam was missing or eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut.

The LO2 ET/ORB umbilical sustained TPS damage at both inboard and outboard forward corners. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. Some of the divots spanned the full width of the cable tray. Lightning contact strips across the forward part of the umbilical and at the 8 o'clock position were missing. Loss of lightning contact strips was also the subject of a previous IFA.

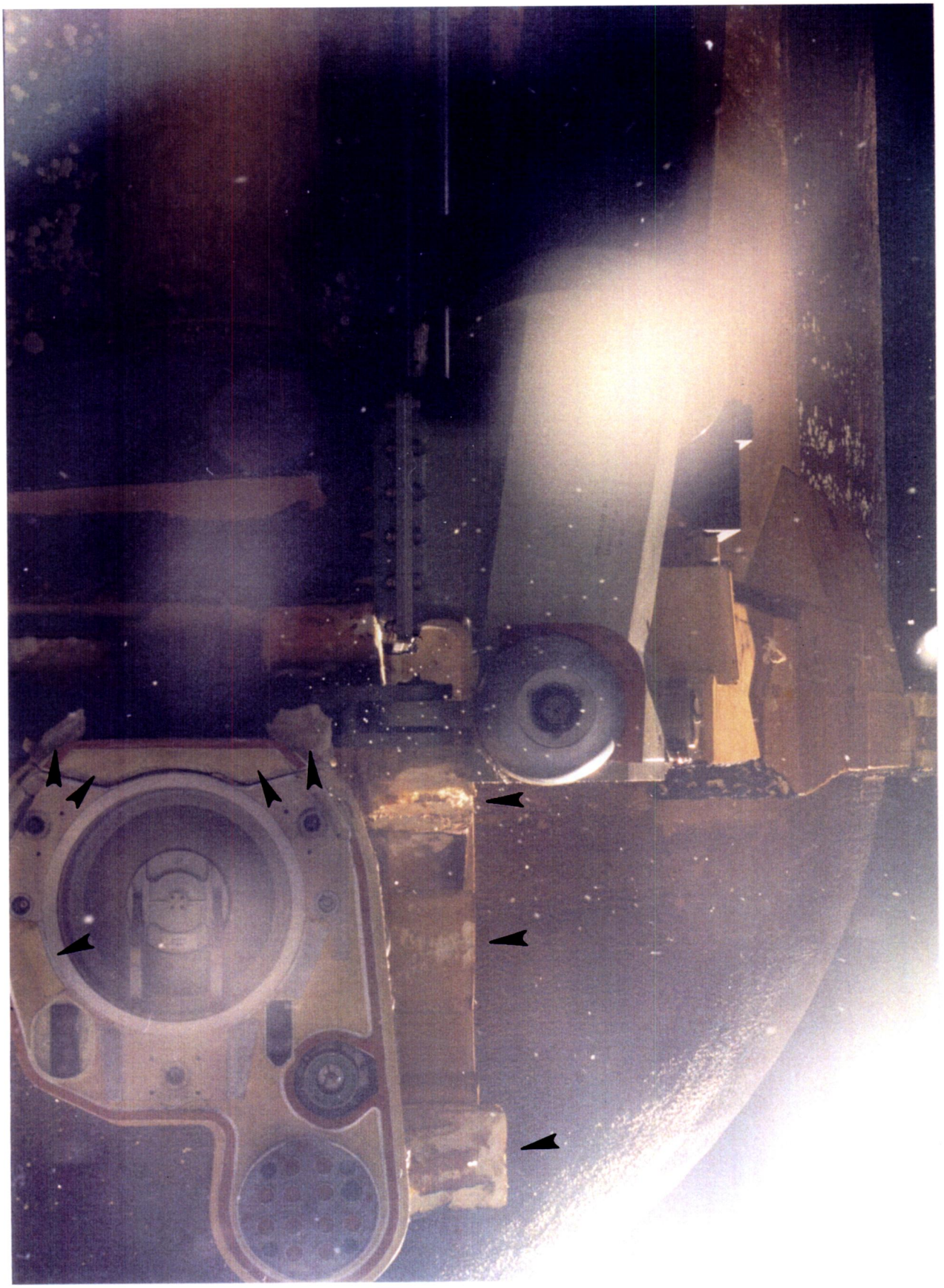


**Photo 17: LO2 ET/ORB Umbilical After ET Separation**

The LO2 ET/ORB umbilical sustained TPS damage at both inboard and outboard forward corners. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. Lightning contact strips across the forward part of the umbilical and at the 8 o'clock position were missing. Loss of lightning contact strips were the subject of a previous IFA.

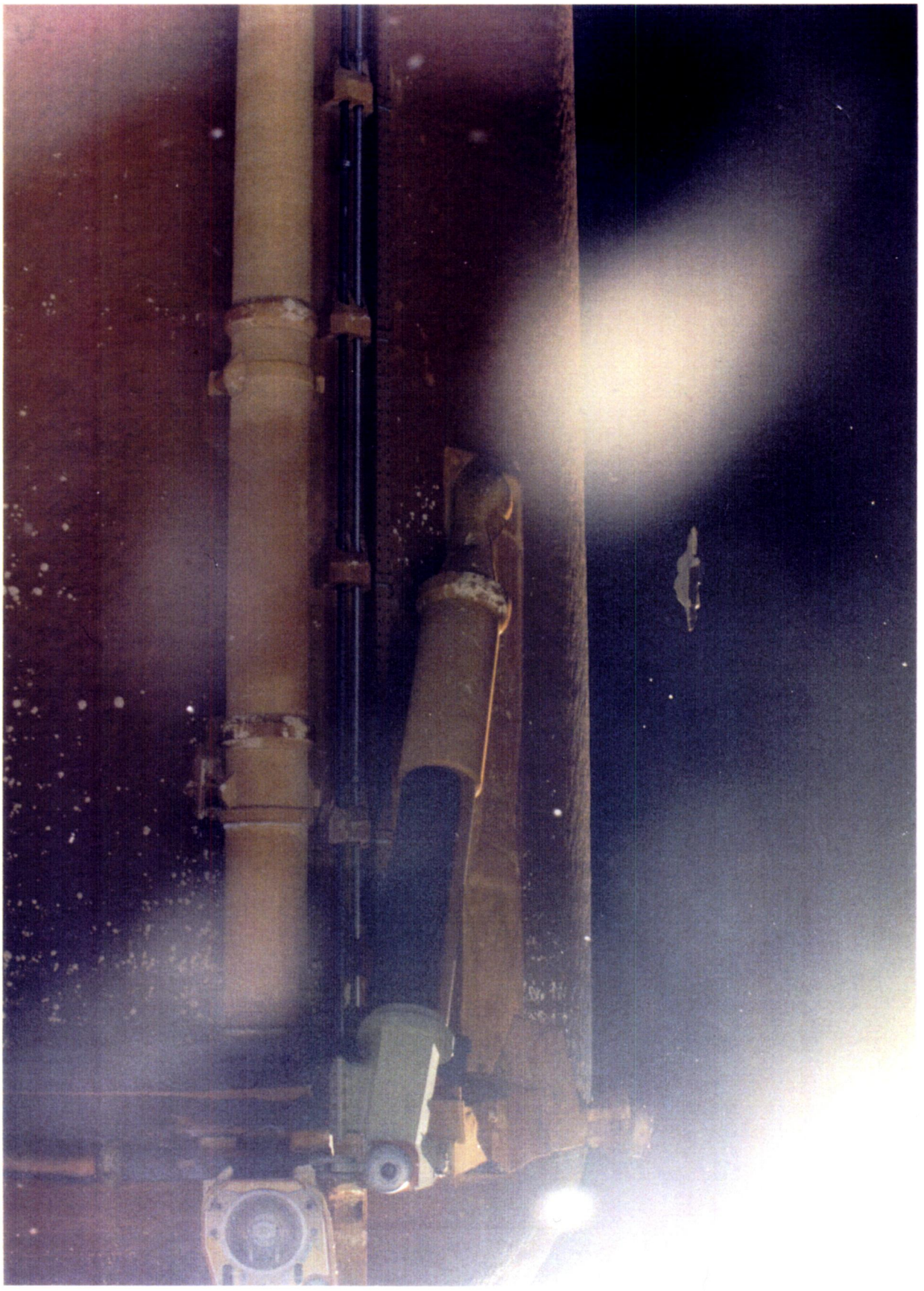


**Photo 18: Small Piece of External Tank Foam**

A small piece of foam insulation drifted by the camera lens shortly after separation of the ET from the Orbiter. Since one side of the foam piece appears charred or blackened, the foam most likely originated from the LO2 ET/ORB umbilical or cable tray area.

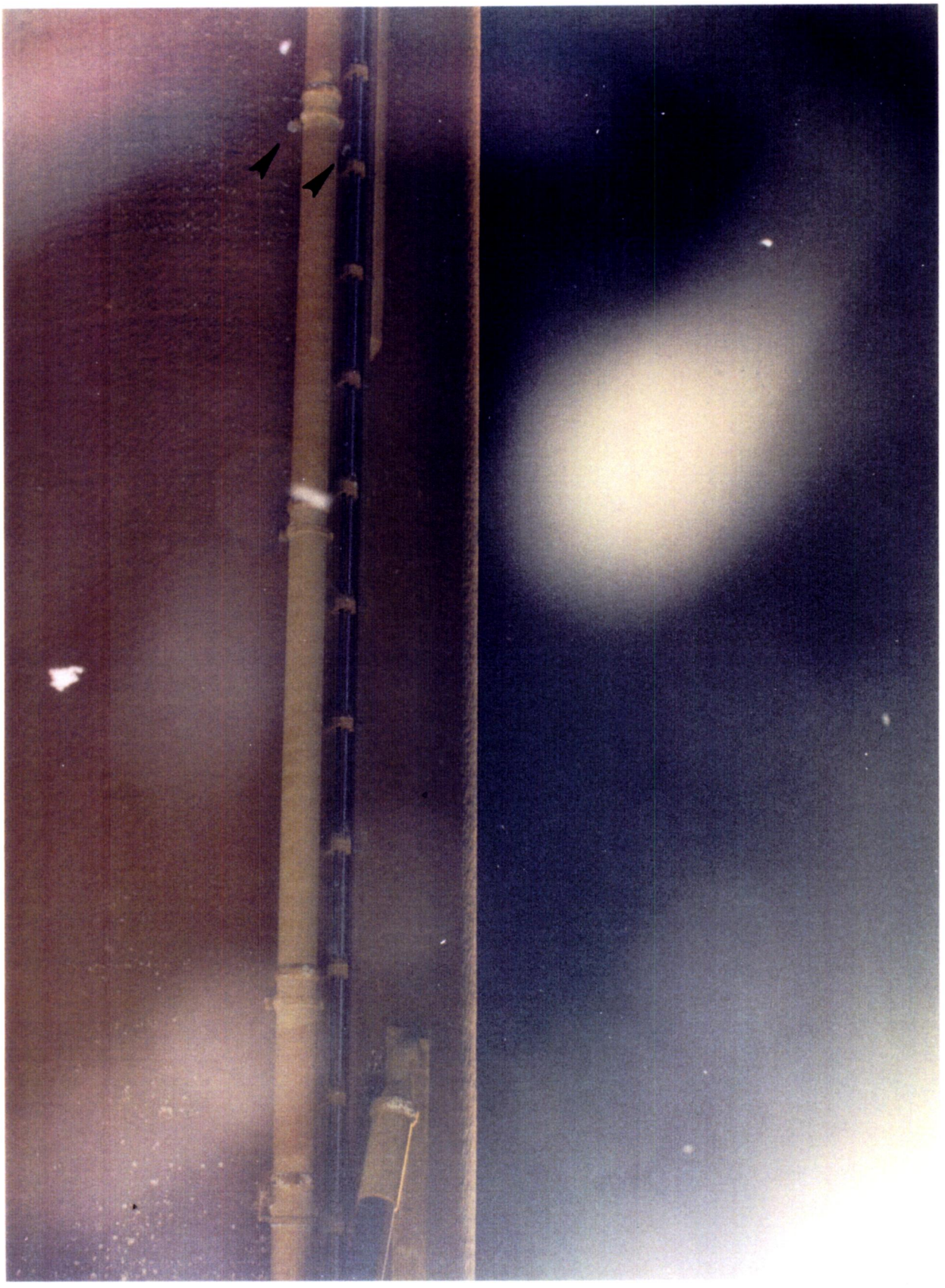


**Photo 19: ET LH2 Tank Acreage Divots**

The LH2 tank acreage was generally in good condition with the exception of one 5-inch diameter divot near the LO2 feedline at station XT-1377 and one 5-inch divot between the LO2 feedline and the pressurization line support at station XT-1377. The divots appeared to expose substrate by showing primer.

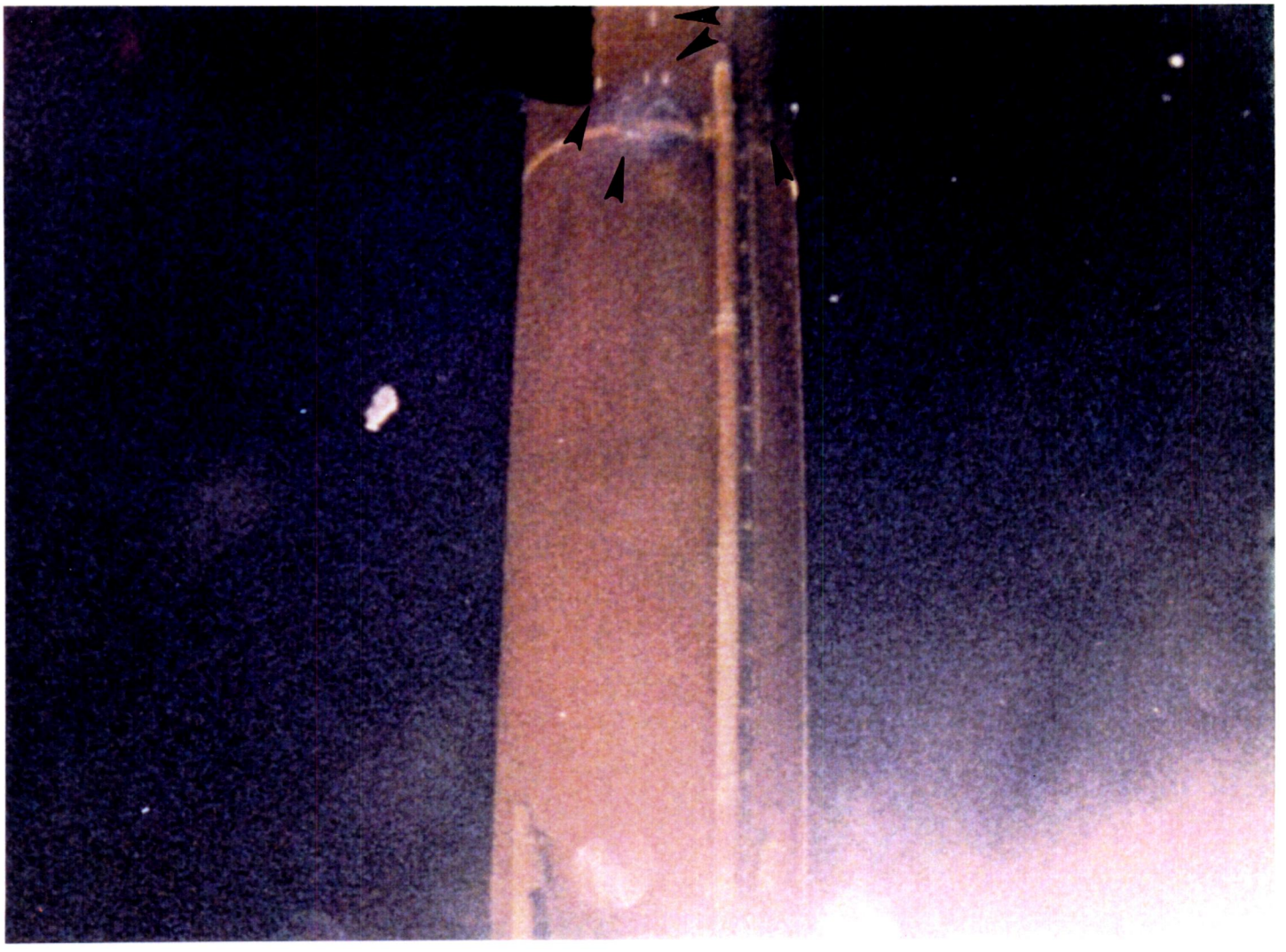


**Photo 20: ET Intertank Divots**

Stringer head divots, ranging in length from 12 to 24 inches, were observed on the intertank acreage: 2 divots forward of the bipods at station XT-1080; 1 divot forward of the bipods on centerline at station XT-960; 1 divot forward of the LO2 feedline fairing at station XT-860; 1 divot forward and outboard of the -Y bipod spindle housing at station XT-1080; and three divots between the LO2 feedline and the +Y EB fitting at station XT-1080. The loss of foam from these intertank divots contributed to the 149 (greater than average) number of hits on the Orbiter lower surface. This type of divot had been the subject of an IFA previously. The redesigned bipod jack pad closeouts were intact. One shallow divot occurred in the LH2 tank acreage aft of the -Y bipod spindle housing closeout.

## 5.3 LANDING FILM AND VIDEO SUMMARY

A total of 23 films and videos, which included two 16mm high speed films, eight 35mm large format films and thirteen videos, were reviewed.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. Wing tip vortices on final approach were visible due to the amount of moisture in the air at the time of landing.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was almost simultaneous.

Drag chute deployment appeared nominal. The drag chute door, caught in the aerodynamic flow aft of the Orbiter, bounced along the runway and into the grass on the west sideline.

Touchdown of the nose landing gear was smooth. The Orbiter drifted east at touchdown with the right main landing gear crossing the runway centerline. The Orbiter corrected back to centerline after the drag chute was deployed.

No significant TPS damage was visible during rollout with the exception of one tile damage site on the right chine lower surface. Rollout and wheel stop were uneventful.

A large format 35mm camera was positioned in line with the runway threshold line to determine the altitude of the Orbiter crossing the runway threshold using photographic means. That value would then be compared at JSC to the Orbiter on-board instrumentation. Measurements on the film were taken when the left main landing gear tire was centered over the 10 foot wide threshold line at GMT 14:54:27.901. An altitude of 17.6 feet from the lowest point on the left main gear tire to the runway surface was calculated.

# 6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-072 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 30 June 1995. 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. The number of debonds (32) over fasteners was average (Figure 1). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position.

The RH forward skirt was missing no TPS. One MSA-2 debond over a bolt head was located near the +Z axis close to XB-523. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins were missing from the frustum severance ring.

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

Separation of the aft ET/SRB struts appeared normal. No K5NA was missing from the separation plane of the upper strut fairing. The ETA ring, IEA, and IEA covers appeared undamaged. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited typical delamination. Aft skirt MSA-2 was missing from fastener heads in six places. Most of the MSA-2 divots, the largest of which measured 4-inches by 2.5-inches in size, appeared to expose lightly-sooted substrate. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

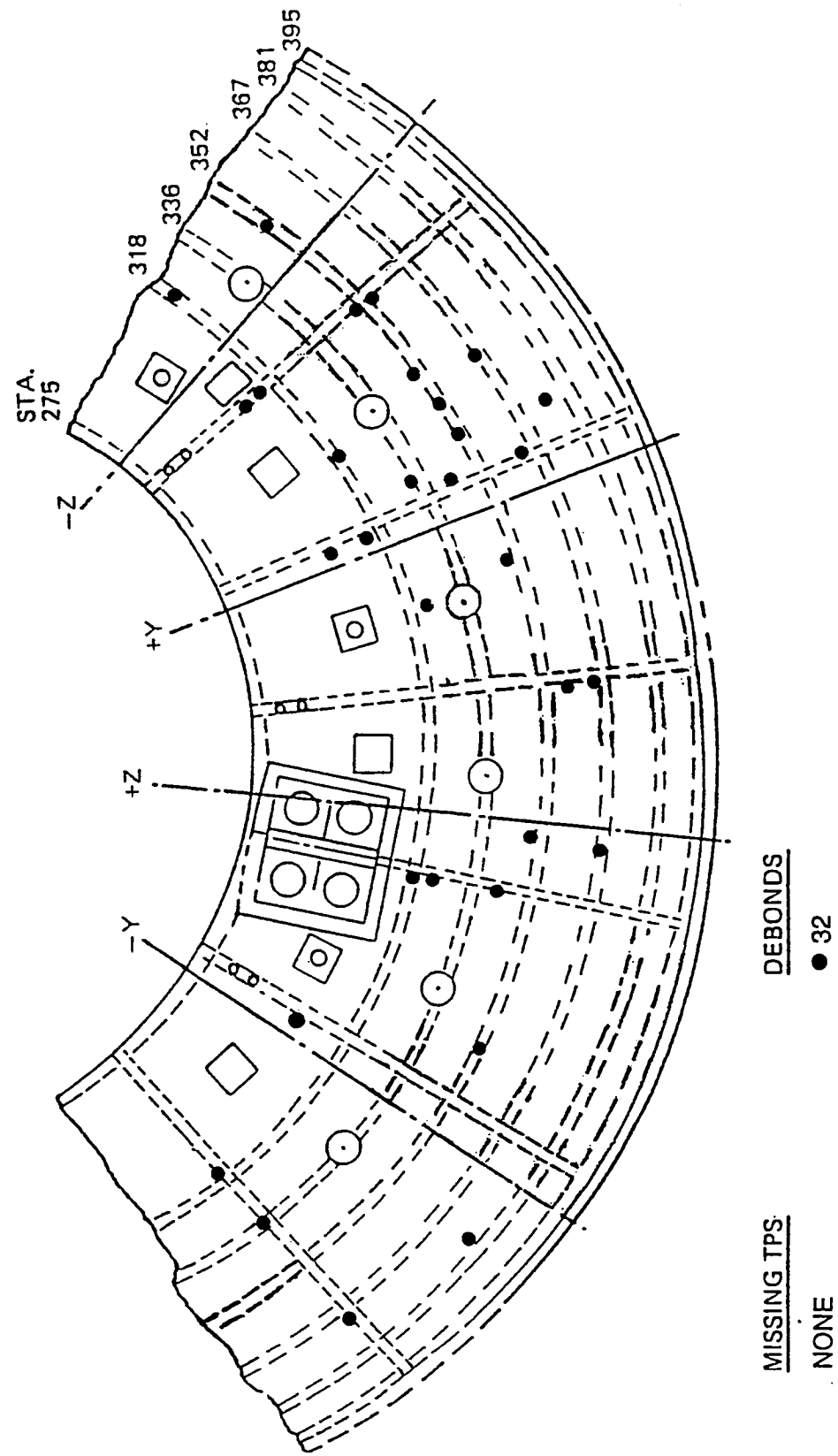



**Figure 1 : RH SRB Frustum**

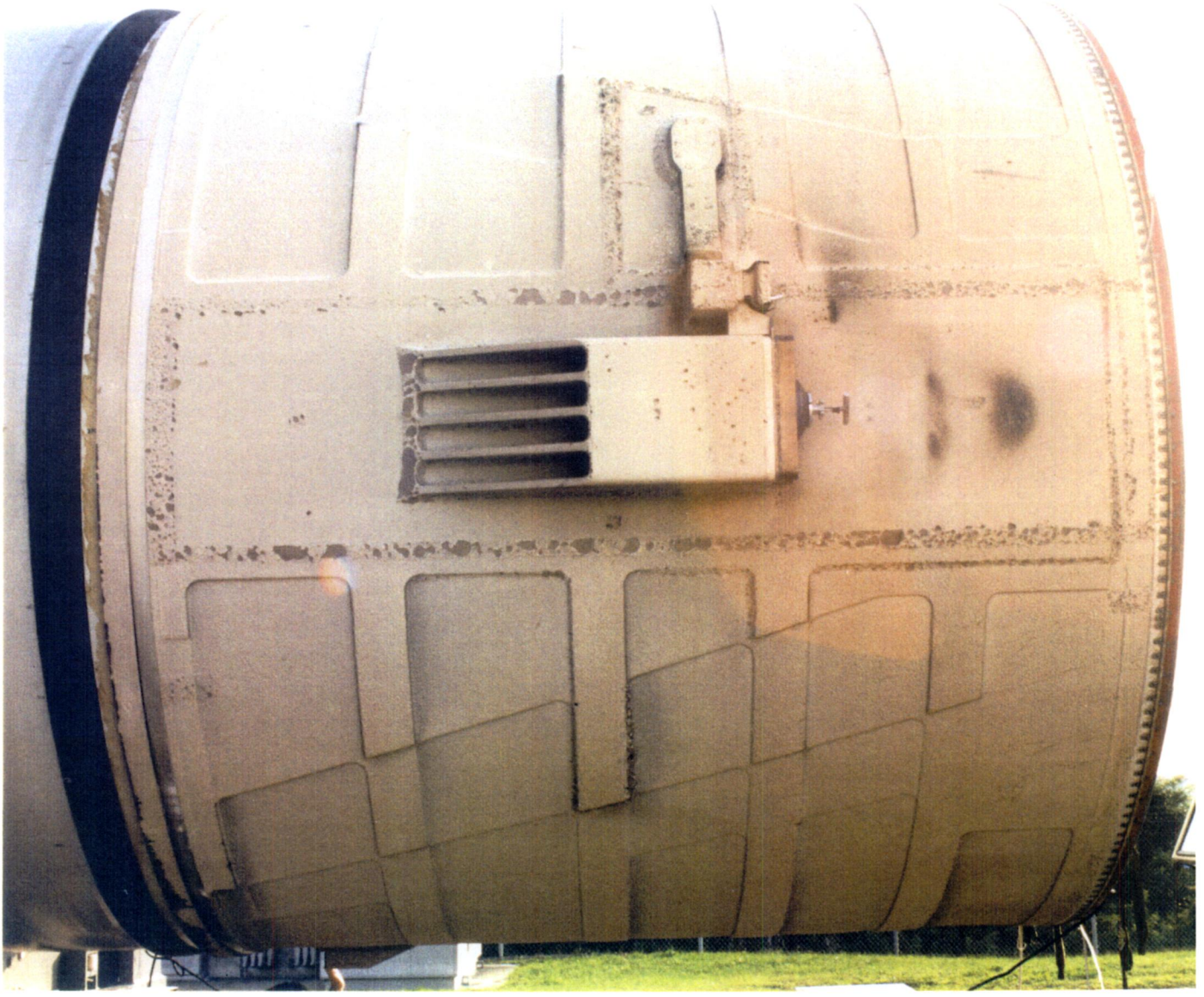


**Photo 21: RH Forward Skirt**


**Photo 22: RH Aft Booster/Aft Skirt**

Aft skirt MSA-2 was missing from fastener heads in six places. Most of the MSA-2 divots, the largest of which measured 4-inches by 2.5-inches in size, appeared to expose lightly-sooted substrate.

## 6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing one 2-inch diameter piece of TPS (divot) near the XB-395 ring frame between the +Y/+Z axes. The exposed substrate appeared darkened and was sampled (Squawk 71002) for laboratory analysis. USBI Report LAN-031-95MP showed the divot was caused by a debond of the MSA-2 from the PR-1422. The divot occurred after BSM firing (absence of sooting) but sometime during re-entry (heating effects). The number of MSA-2 debonds over fasteners (52) and in the acreage (4) was somewhat greater than average (Figure 2). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position.

The LH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the 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. No K5NA was missing from the separation plane of the upper strut fairing. However, the fairing was deformed and missing aft-facing insulation as a result of water impact (clean substrate). The ETA ring, IEA, and IEA covers, appeared undamaged, though foam was missing from the aft side of the IEA. All three of the stiffener rings were cracked from water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited typical delamination. Aft skirt MSA-2 was missing from fastener heads in eight places and debonded in three places. The MSA-2 divots were located along the XB-1860 and XB-1894 ring frames. Hypalon paint was blistered over areas where BTA closeouts had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

SRB Post Launch Anomalies are listed in Section 9.

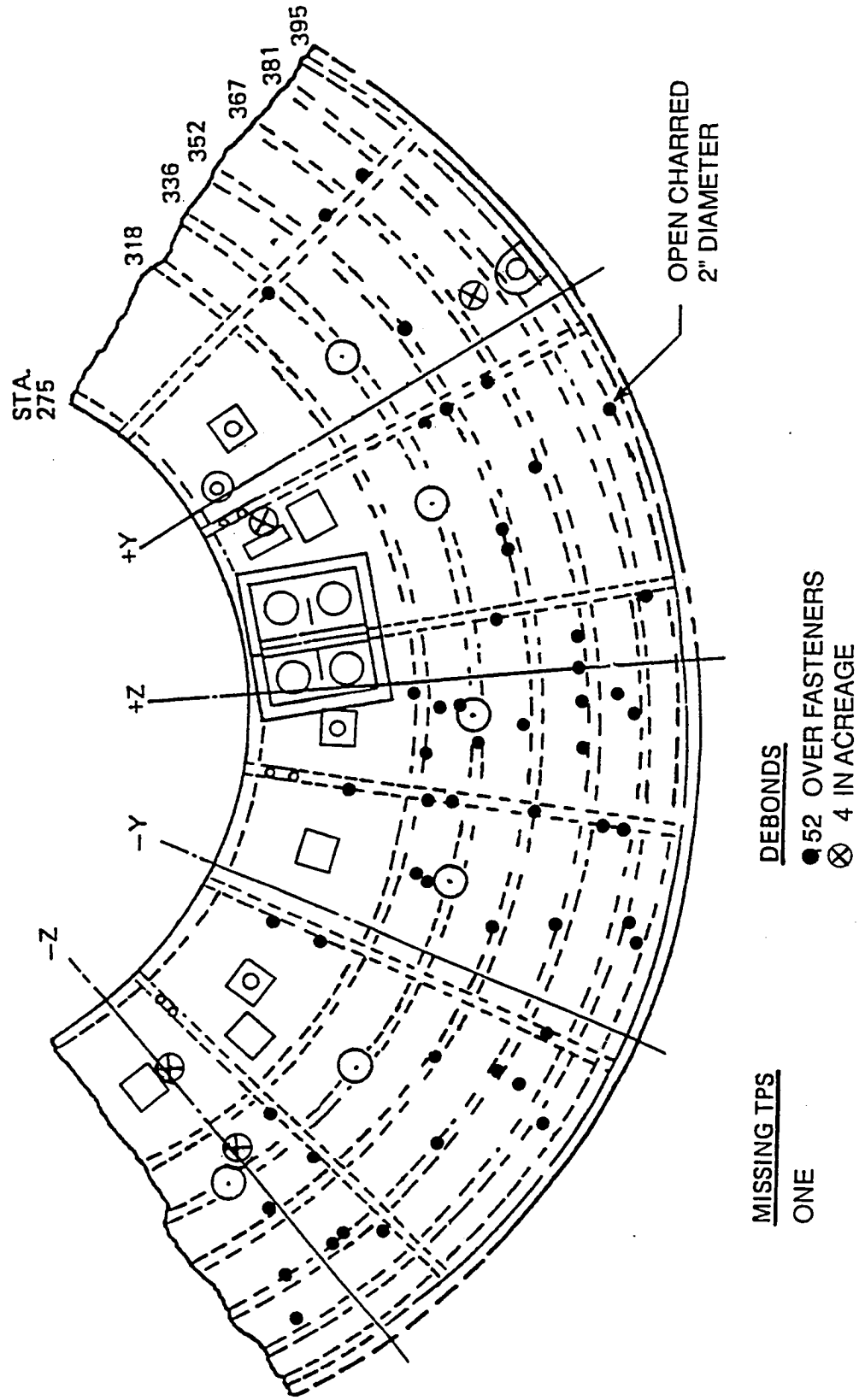



**Figure 2 : LH SRB Frustum**

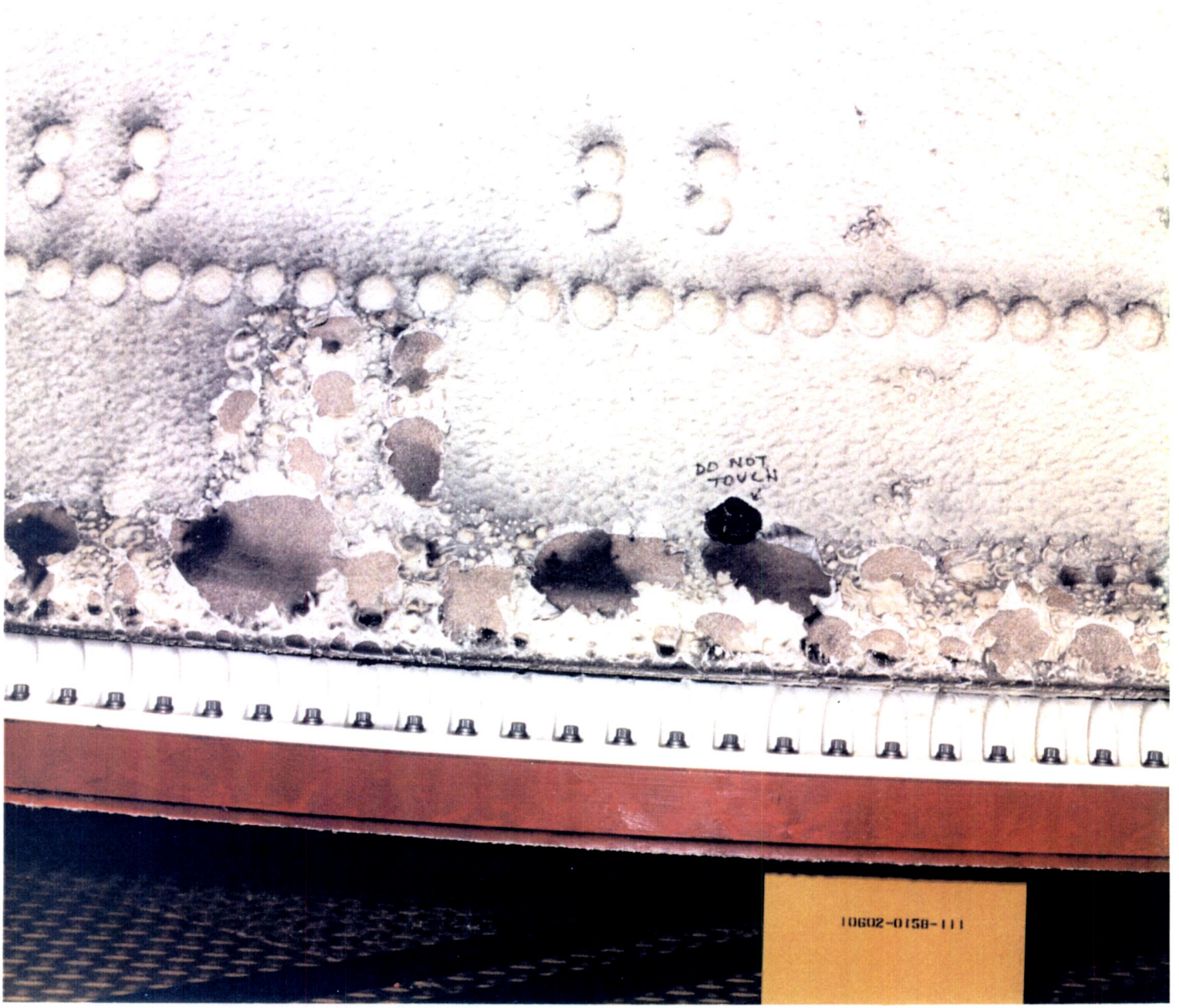



**Photo 23: LH Frustum**

The LH frustum was missing one 2-inch diameter piece of TPS (divot) near the XB-395 ring frame between the +Y/+Z axes. The exposed substrate appeared darkened. Laboratory analysis showed the divot was caused by a debond of the MSA-2 from the PR-1422. The divot occurred after BSM firing (absence of sooting) but sometime during re-entry (heating effects). Hypalon paint was blistered/missing where BTA closeouts had been applied.

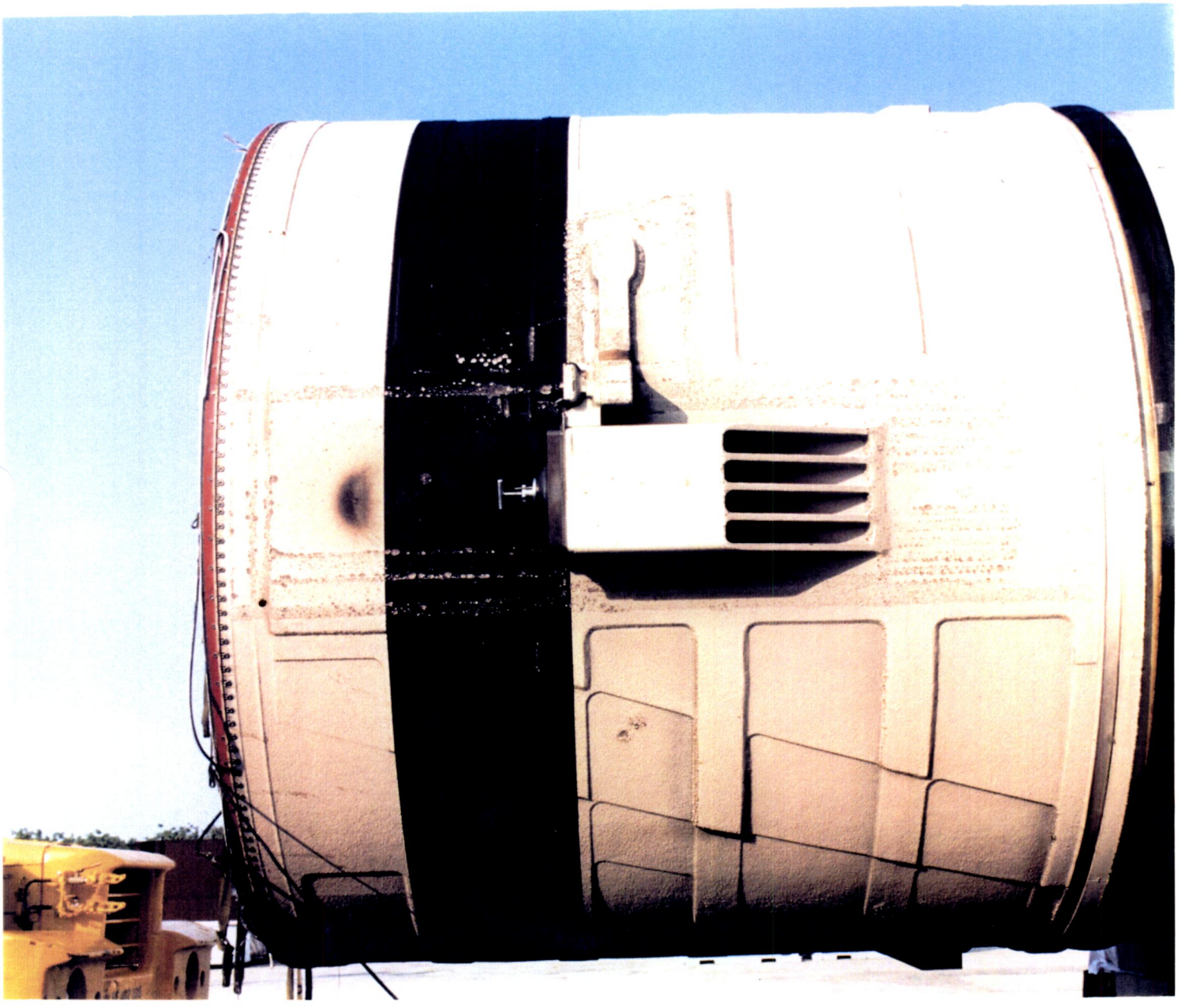


**Photo 24: LH Forward Skirt**


**Photo 25: LH Aft Booster/ Aft Skirt**

Aft skirt MSA-2 was missing from fastener heads in eight places and debonded in three places. The MSA-2 divots were located along the XB-1860 and XB-1894 ring frames. Hypalon paint was blistered over areas where BTA closeouts had been applied.

## 7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-104 Atlantis was conducted 7-9 July 1995 at the Kennedy Space Center on SLF runway 15 and in the Orbiter Processing Facility bay #2. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 164 hits, of which 25 had a major dimension of 1-inch or larger. 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 53 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger was greater than average (Reference Figures 3-4. Note: No debris impacts were detected on both the left and right sides of the Orbiter. Therefore, the corresponding maps have been omitted).

The following table breaks down the STS-71 Orbiter debris damage by area:

| | HITS > 1" | TOTAL HITS |
|---|---|---|
| Lower surface | 24 | 149 |
| Upper surface | 1 | 10 |
| Right side | 0 | 0 |
| Left side | 0 | 0 |
| Right OMS Pod | 0 | 2 |
| Left OMS Pod | 0 | 3 |
| TOTALS | 25 | 164 |

The Orbiter lower surface sustained a total of 149 hits, of which 24 had a major dimension of 1-inch or larger. Most of the tile debris damage sites were located to the right of centerline on the lower surface. The loss of foam insulation from the ET intertank during flight contributed to the number of tile damage sites.

The tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals, which are believed to be caused by impacts from umbilical ice, were typical in number and size.

No tile damage from micrometeorites or on-orbit debris have been identified to date.

The tires and brakes were reported to be in good condition for a landing on the KSC concrete runway.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned nominally. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. Umbilical closeout foam, 6 inches long by 3/4-inch wide by 3/4-inch thick, along with a 1-inch long by 3/4-inch wide piece of the white RTV dam, adhered to the umbilical plate near the LH2 recirculation line disconnect. Residue/particulate matter coated the ET/ORB umbilical cavities forward of the umbilical plates and along the LH2 umbilical cavity aft thermal barrier. No debris was found on the runway beneath the ET/ORB umbilicals.

Orbiter windows #3 and #4 exhibited moderate hazing. A light haze was present on the other windows. Tile damage on the window perimeter tiles was significantly less than usual. Four damage sites in a perimeter tile above window #3 was not caused by a debris impact. A previously repaired area had shaken loose during flight. A concerted effort had been made to minimize the RTV used for attaching paper covers to FRCS thrusters.

No ice adhered to the payload bay door. A white residue was present around the waste water dump nozzle. No unusual tile damage occurred on the leading edges of the OMS pods. Three tile damage sites were detected on the leading edge of the vertical stabilizer.

Tile damage on the base heat shield was typical. All three Dome Mounted Heat Shield (DMHS) closeout blankets were in excellent condition. Tiles on the vertical stabilizer "stinger" were intact and undamaged. One tile near the lower right corner the drag chute door was slightly damaged when the door opened. Numerous tile damage sites on the +Z side of the body flap outboard of SSME #3 corresponded to sites identified in the launch film review and were caused by SSME ignition vibration/acoustics. A piece of tile, 3-inches long by 2-inches wide by 1/2-inch thick was missing from this same general area near the body flap hinge line. A gap filler protruded 1/2 inch from a body flap tile near the hinge line adjacent to SSME #2.

The post landing walkdown of Runway 15 was performed immediately after landing. No flight hardware was found on the runway with the exception of a 3/4-inch piece of red RTV from the main landing gear pressure transducer instrumentation. All Orbiter drag chute hardware was recovered and appeared to have functioned normally.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger was somewhat greater than average when compared to previous missions (Figures 5-6).

Orbiter Post Launch Debris Anomalies are listed in Section 9.

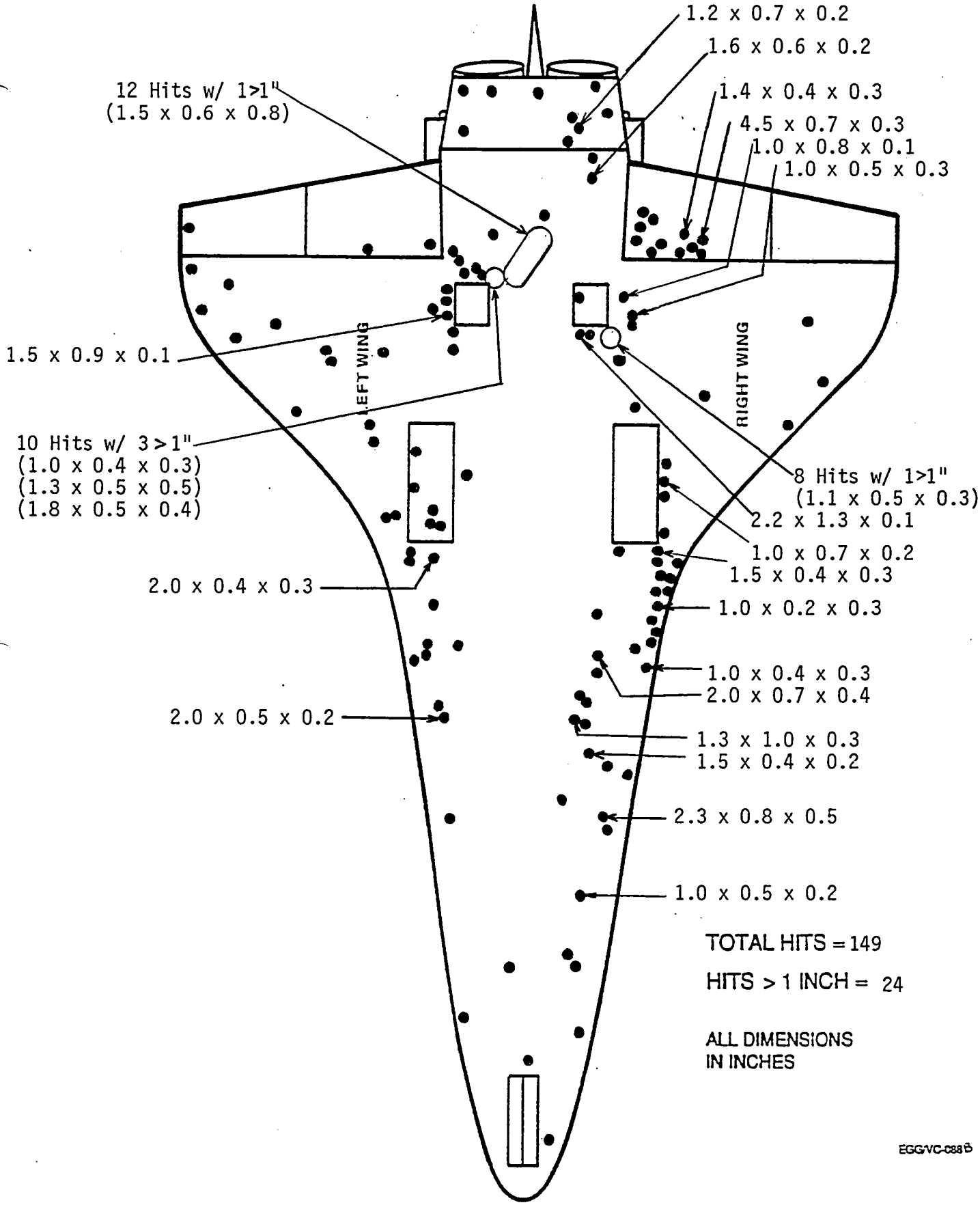



**Figure 3 : Orbiter Lower Surface Debris Map**

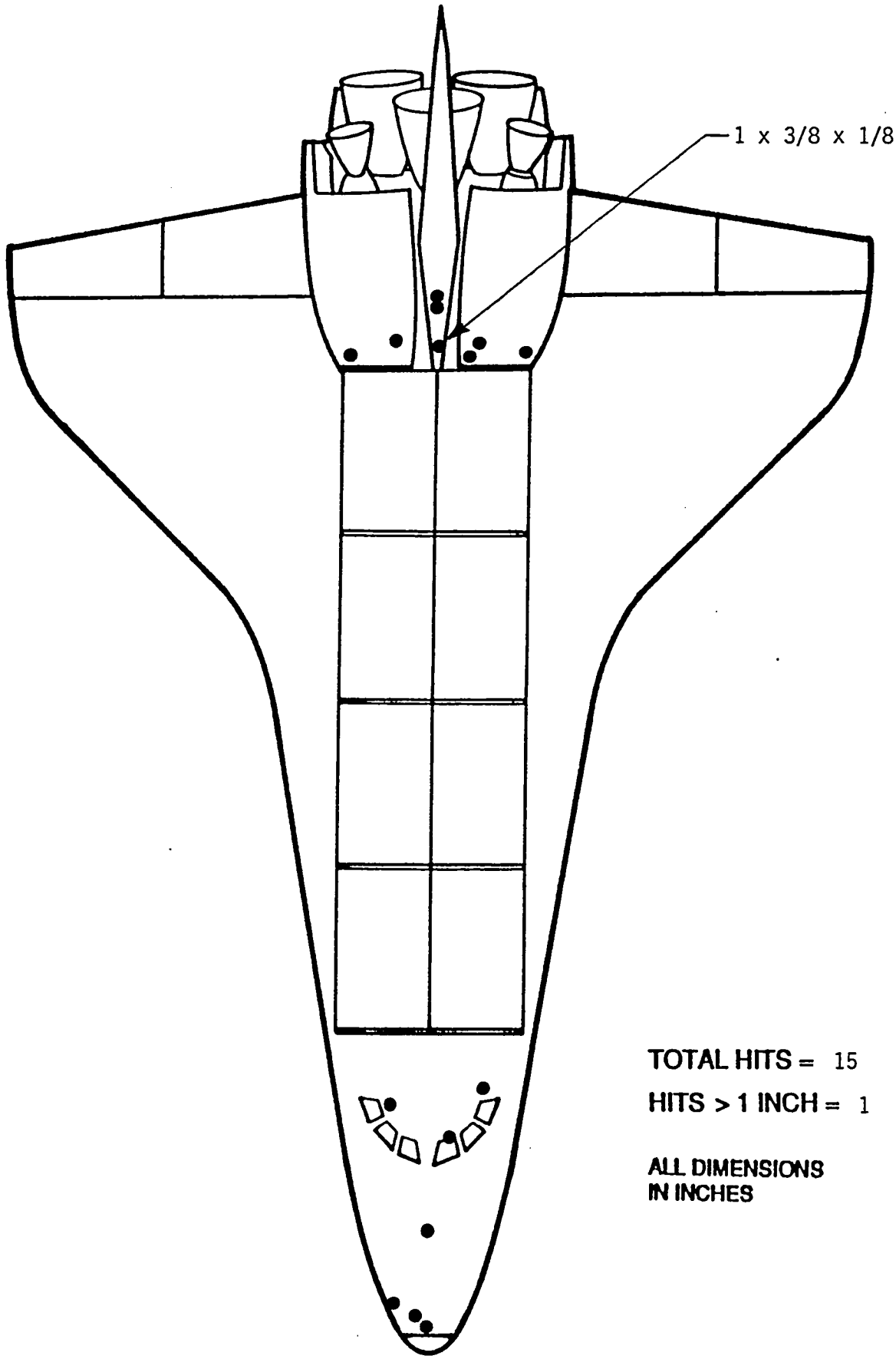



**Figure 4 : Orbiter Upper Surface Debris Map**

| | 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 |
| STS-64 | 18 | 116 | 19 | 150 |
| STS-68 | 9 | 59 | 15 | 110 |
| STS-66 | 22 | 111 | 28 | 148 |
| STS-63 | 7 | 84 | 14 | 125 |
| STS-67 | 11 | 47 | 13 | 76 |
| AVERAGE | 13.9 | 89.5 | 21.0 | 130.4 |
| SIGMA | 7.1 | 42.9 | 9.9 | 55.0 |
| STS-71 | 24 | 149 | 25 | 164 |

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

**Figure 5 : Orbiter Post Flight Debris Damage Summary**

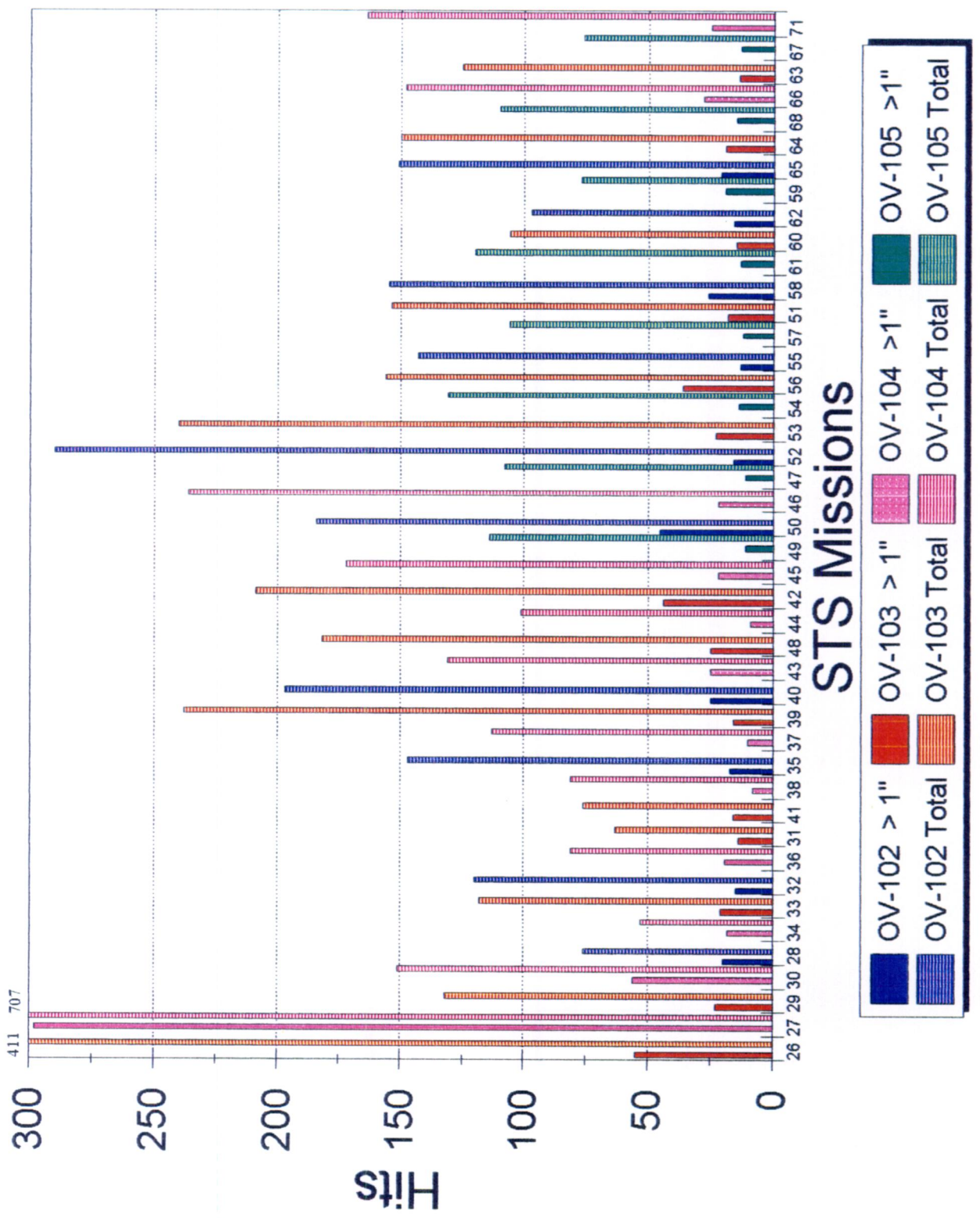



**Figure 6 : Orbiter Debris Damage Comparison Chart**


**Photo 26: Overall View of Orbiter Right Side**

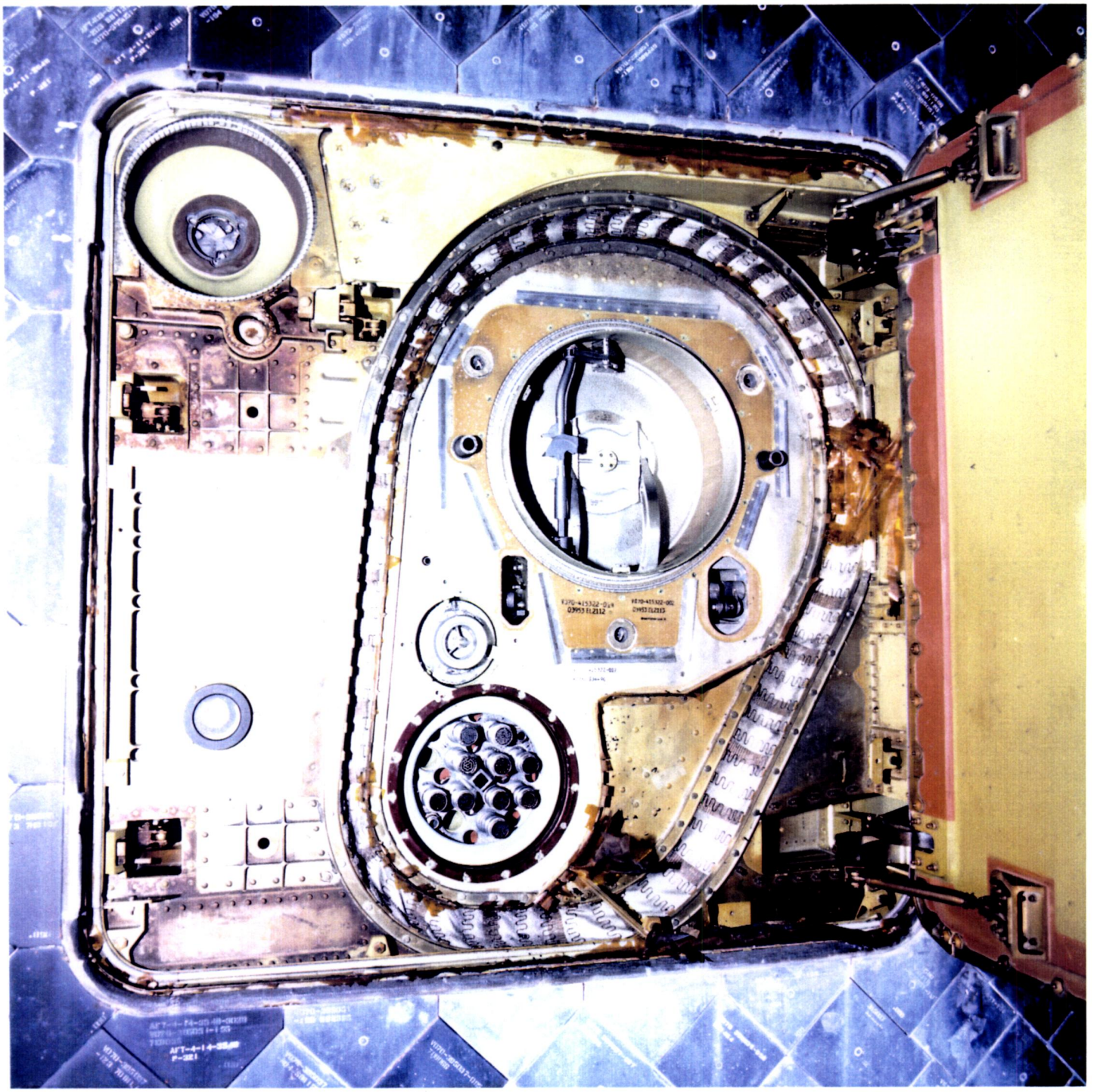


**Photo 27: LO2 ET/ORB Umbilical**

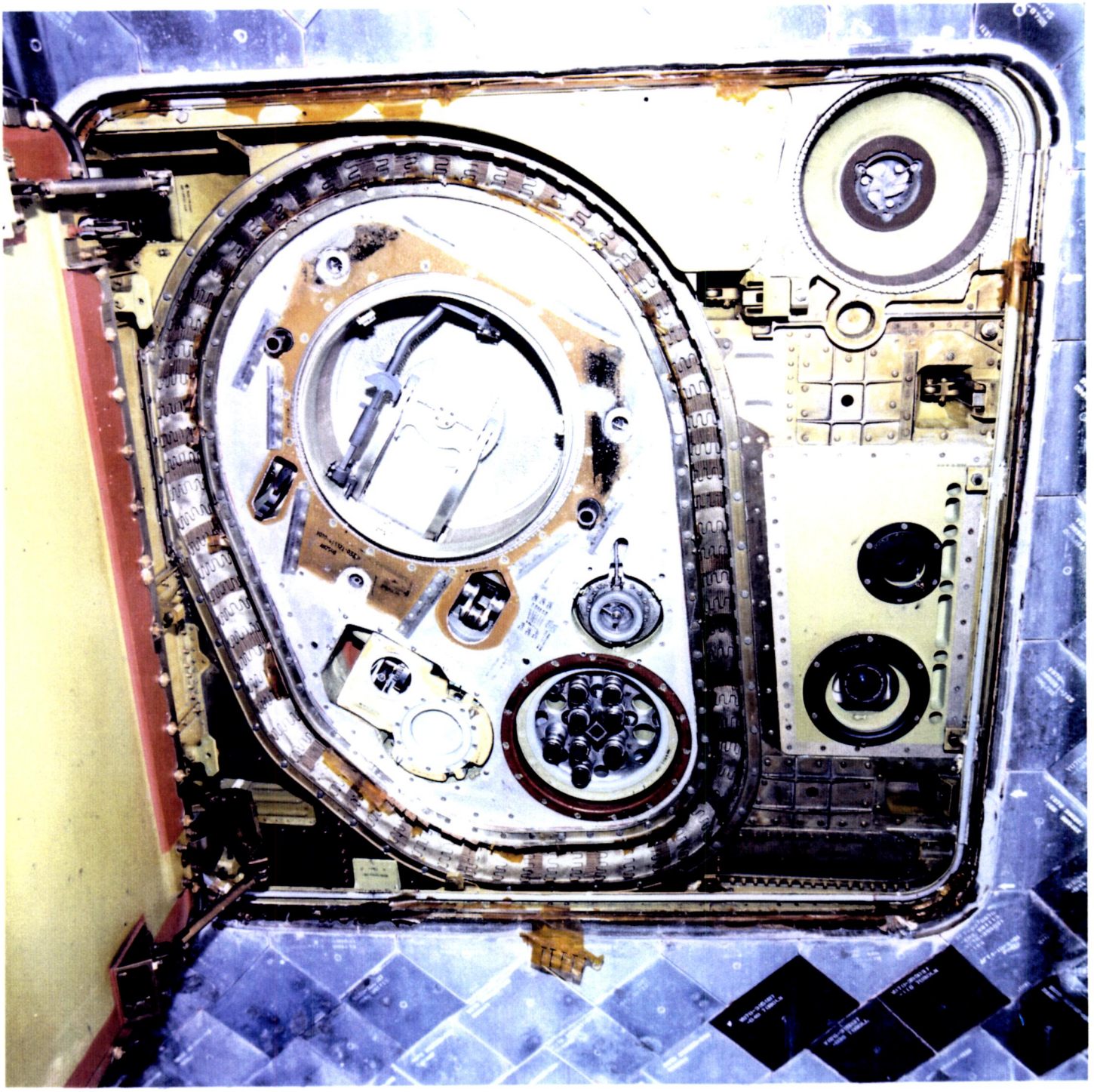


**Photo 28: LH2 ET/ORB Umbilical**

**Photo 29: Debris and Exhaust Residue**

Exhaust residue, small TPS particles, and debris had accumulated on both LH2 and LO2 ET/ORB umbilical plates during ascent

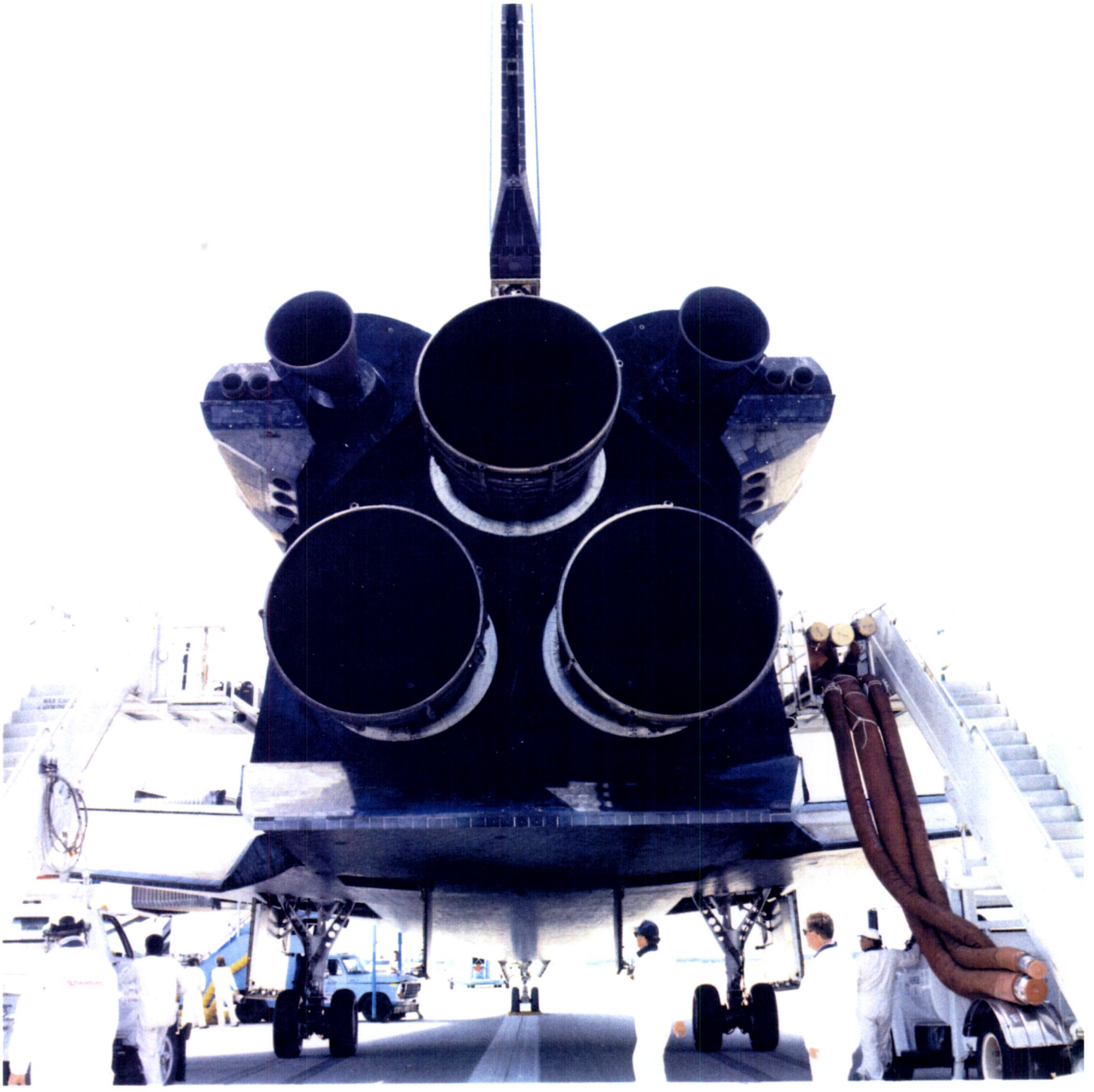


**Photo 30: Base Heat Shield**

Base heat shield tiles and SSME Dome Mounted Heat Shield closeout blankets were in good condition

**Photo 31: Orbiter Windows**

Orbiter windows #3 and #4 exhibited moderate hazing. A light haze was present on the other windows. Tile damage on the window perimeter tiles was significantly less than usual. Four damage sites in a perimeter tile above window #3 was not caused by a debris impact. A previously repaired area had shaken loose during flight. A concerted effort had been made to minimize the RTV used for attaching paper covers to FRCS thrusters.

# 8.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-104 Atlantis during the STS-71 post landing debris assessment at Kennedy Space Center. 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 facility environment, SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (RTV, tile, tile repair, and glass insulation), Orbiter RCS nozzle cover adhesive, paints and primer from various sources. There was no apparent vehicle damage related to these residuals.

## 8.2 ORGANIC ANALYSIS

The results of the STS-71 organic analysis indicated the presence of plastic polymers (Orbiter window covers) and RTV (Orbiter Thermal Protection System and Orbiter RCS nozzle cover adhesive). These types of organic particulate are consistent with those of the last several STS flights.

## 8.3 STS-67 ORGANIC ANALYSIS

The results of the recently-received STS-67 organic sample analysis indicated the presence of plastic polymers (Orbiter window covers) and RTV (Orbiter Thermal Protection System and Orbiter RCS nozzle cover adhesive). Additional laboratory reference sample testing of SRB sealant revealed a similar fingerprint to that found in previous window wipe sample testing.

## 8.4 NEW FINDINGS

This set of post-flight debris residual samples led to no new findings, although the variety of residual material continues to be representative of that documented in previous mission sampling (Reference Figure 7). An apparent match was documented in laboratory reference testing of SRB sealant (polysulfide) to previous mission window wipe sample testing.

| STS | Sample Location | | | | |
|---|---|---|---|---|---|
| | Windows | Wing RCC | Lower Tile Surface | Umbilical | Other |
| 71 | Metallics - Fac. Env./BSM Residue (SRB)<br>RTV, Tile, Tile filler (ORB TPS)<br>Insulation Glass (ORB TPS)<br>Earth minerals (landing site)<br>Organics-Plastic polymers, SRB sealant<br>RTV-RCS thruster nozzle cover<br>Paint and primer | | | | |
| 67 | Metallics - Fac.Env./BSM Residue (SRB)<br>Tile, Tile filler (ORB TPS)<br>Insulation Glass (ORB TPS)<br>Fiber-sample cloth<br>Earth minerals (Landing site)<br>Organics-RTV, Plastic polymers<br>Paint and primer | | | | SRB sealant sample:<br>laboratory reference |
| 63 | Metallics - Fac. Env./BSM Residue (SRB)<br>RTV, Tile, Tile filler (ORB TPS)<br>Insulation Glass (ORB TPS)<br>Building type insulation<br>Fiber-sample cloth<br>Earth minerals (landing site)<br>Organics-Plastic polymers, SRB sealant<br>RTV-RCS thruster nozzle cover<br>Paint and primer | | Silica-rich tile (ORB TPS)<br>Hypalon paint (SRB) | | |
| 66 | Metallics - Fac.Env./BSM Residue (SRB)<br>RTV, Tile, Tile filler (ORB TPS)<br>Insulation Glass (ORB TPS)<br>Fiber-sample cloth<br>Earth minerals (Landing site)<br>Organics-Plastic polymers, SRB sealant<br>RTV-RCS thruster nozzle cover<br>Paint and primer | | Silica-rich tile (ORB-TPS)<br>Hypalon paint (SRB) | | |
| 68 | Metallics - Fac.Env./BSM Residue (SRB)<br>RTV, Tile, Tile filler (ORB TPS)<br>Insulation Glass (ORB TPS)<br>Fiber-sample cloth<br>Earth minerals (Landing site)<br>Organics-Plastic polymers, SRB sealant<br>RTV-RCS thruster nozzle cover<br>Paint and primer | | Silica-rich tile (ORB-TPS)<br>Hypalon paint (SRB) | | ET GOX Vent Seal land area and<br>GOX Seal Sample-<br>Metallic Particulate<br>WINDOW DEBRIS SAMPLE- 'Butch<br>Paper' |
| 64 | Metallics - Fac.Env./BSM Residue (SRB)<br>RTV, Tile, Tile filler (ORB TPS)<br>Insulation Glass (ORB TPS)<br>Fiber-sample cloth<br>Earth minerals (Landing site)<br>Organics-Plastic polymers, SRB sealant<br>RTV-RCS thruster nozzle cover<br>Paint and primer | | | | |
| | | | | | |

For data on previous missions refer to mission reports prior to STS-59

**Figure 7 : Orbiter Post Landing Microchemical Sample Results**

## 9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 9 post launch anomalies, but no In-Flight Anomalies (IFA's), were observed on the STS-71 mission.

### 9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. The GOX vent seals stuck momentarily to the ET nose cone during hood retraction at T-2:30 minutes. Numerous small pieces of topcoat were pulled loose from both footprint areas and adhered to the seals.

2. A rigid object, approximately 7-inches long by 2-inches wide by 1/2-inch thick, was ejected out of the LH SRB exhaust hole near HDP #7 at GMT 19:32:20.186. The object, which may have been a piece of brick from the flame trench, moved away from the vehicle.

### 9.2 SOLID ROCKET BOOSTERS

1. The LH frustum was missing one 2-inch diameter piece of TPS near the XB-395 ring frame between the +Y/+Z axes. The exposed substrate was sooted. The number of MSA-2 debonds over fasteners (52) and in the acreage (4) was somewhat greater than average

### 9.3 EXTERNAL TANK

1. Eight stringer head divots, ranging in length from 12 to 24 inches, were observed on the intertank acreage: two divots forward of the bipods at station XT-1080; one divot forward of the bipods on centerline at station XT-960; one divot forward of the LO2 feedline fairing at station XT-860; one divot forward and outboard of the -Y bipod spindle housing at station XT-1080; and three divots between the LO2 feedline and the +Y EB fitting at station XT-1080. The loss of foam from these intertank divots contributed to the 149 (greater than average) number of hits on the Orbiter lower surface. This type of divot had been the subject of an IFA previously. Stringer head cleaning and worker walk load procedures were modified as a result of the IFA effective ET-74.

2. The LH2 tank acreage: one shallow divot at the flange closeout interface aft of the -Y bipod spindle housing closeout; one 5-inch diameter divot near the LO2 feedline at station XT-1377; and one 5-inch divot between the LO2 feedline and the press line support at station XT-1377.

3. Lightning contact strips across the forward part and at the 8 o'clock position of the LO2 ET/ORB umbilical were missing. Loss of lightning contact strips was also the subject of a previous IFA.

### 9.4 ORBITER

1. Oxidizer vapors exited aft RCS thruster R2U as the paper cover ruptured during SSME ignition. This thruster had exhibited signs of a very small leak prior to launch.

2. Umbilical closeout foam, 6 inches long by 3/4-inch wide by 3/4-inch thick, along with a 1-inch long by 3/4-inch wide piece of the white RTV dam, adhered to the umbilical plate near the LH2 recirculation line disconnect.

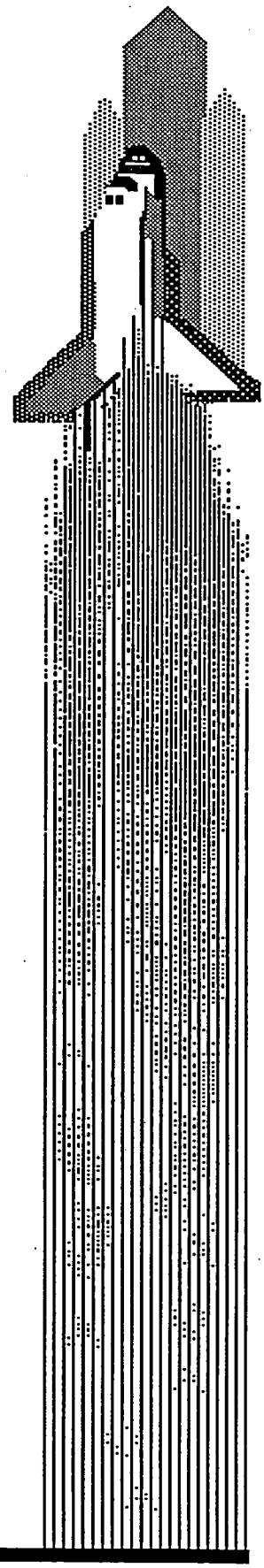
3. The only flight hardware found on the runway was a 3/4-inch piece of red RTV from the main landing gear pressure transducer instrumentation.

# APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

# Space Shuttle

Earth Science Branch

Image Science and
Analysis Group



## STS-71 Summary of Significant Events

August 11, 1995

# Space Shuttle Image Science and Analysis Group

## STS-71 Summary of Significant Events

Project Work Order - SN-52V

**Approved By**

Lockheed

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**Prepared By**

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Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

# 1. STS-71 (OV-104): FILM/VIDEO SCREENING AND TIMING SUMMARY

## 1.1 SCREENING ACTIVITIES

### 1.1.1 Launch

Atlantis (OV-104) launched on mission STS-71 from pad A at 19:32:18.998 Coordinated Universal Time (UTC) on Tuesday, June 27, 1995 (day 178) as seen on camera E9. Solid rocket booster (SRB) separation occurred at 19:34:22.503 UTC as seen on camera E207.

On launch day, 24 videos were screened. Following launch day, 52 films were reviewed. Camera E54 was a no run. No potential anomalies were observed during launch.

Detailed Test Objective (DTO-312), photography of the external tank after separation, was performed for this mission using Orbiter umbilical well cameras. Handheld photography of the external tank was not acquired on STS-71 because the normal pitch maneuver was not performed due to propellant limitations. A detailed description of DTO-312 is given in Section 2.4.

### 1.1.2 On Orbit

Detailed Test Objective 1118 (MIR Micrometeoroid & Debris Impact Photo Survey) was performed. A ground-controlled survey of the Mir Station's exterior surfaces was accomplished during the first two crew sleep shifts of the docked phase of the STS-71 mission. Detailed views of the Orbiter-facing side of the Kvant-2 and Spektr modules were acquired. Tasks documenting the Station's configuration, analysis of possible damage and discoloration, and assessment of plume impingement are scheduled to be completed by the end of August 1995.

### 1.1.3 Landing

Atlantis landed on runway 15 at KSC on Friday, July 7, 1995. Twelve videos of the Orbiter's approach and landing were received. The SLV North view was not received.

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

## 1.2 TIMING ACTIVITIES

*Launch:*
Videos KTV2, KTV21A, and OTV050 had incorrect timing. The timing in the beginning of KTV5 is incorrect and corrects approximately 11 seconds after launch. All other videos had timing. Film cameras: E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E25, E26, E30, E33, E34, E35, E36, E40, E50, E52, E57, E59, E60, E62, E63, E65, E76, E77, E79, E222, and E224 had in-frame alphanumeric timing. The time codes from videos and films were used to identify specific events during the initial screening process. The remaining launch films had coded IRIG time at the edge of the film. Table 1.2.1 provides the events that were timed.

| Event Description | Time (UTC) | Camera |
|---|---|---|
| Launch | 19:32:18.998 | E9 |
| Condensation - Start | 19:32:53.862 | E222 |
| Condensation - End | 19:33:06.400 | E222 |
| Body Flap Motion - Start | 19:33:01.989 | E207 |
| Body Flap Motion - End | 19:33:15.282 | E207 |
| Recirculation - Start | 19:33:53.086 | E207 |
| Recirculation - End | 19:34:02.347 | E207 |
| SRB Separation | 19:34:22.503 | E207 |

**Table 1.2.1:** Launch Film Timing Events

*Landing*:
Twelve videos were received and screened on landing day. Eight videos: KTV5, KTV6, KTV11, KTV12, KTV13, KTV15, KTV20, and KTV33 had timing. Videos EL17 IR, EL18 IR, Mobile IR, and SLF South did not have timing.

| Event Description | Time (UTC) | Camera |
|---|---|---|
| Landing gear - doors opened | 188:14:54:15.907 | KTV33 |
| *Touchdown* | | |
| Left Main Wheel | 188:14:54:33.975 | KTV33 |
| Right Main Wheel | 188:14:54:34.092 | KTV33 |
| Nose Wheel | 188:14:54:43.985 | KTV33 |
| Wheel stop | 188:14:55:27.997 | KTV11 |

**Table 1.2.2:** Landing Video Timing Events

# 2. SUMMARY OF SIGNIFICANT EVENTS

## 2.1 DEBRIS

### 2.1.1 Debris Near the Time of SSME Ignition

#### 2.1.1.1 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris

(Cameras: E1, E5, E6, E15, E16, E17, E25, E26, E30, E31, E35, E36, E40, OTV009, OTV054, OTV063 )

Normal ice debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. A white piece of debris from the ET/Orbiter umbilicals was seen to strike the umbilical well door sill at T-3.2 seconds (Figure 2.1.1.1 A). Three small light colored pieces of debris appeared to travel upwards and strike the LSRB at 0.4 seconds MET (Figure 2.1.1.1 B). A small white piece of debris appeared to strike the ET aft dome near the LO2 ET/Orbiter umbilical at 0.7 seconds MET (Figure 2.1.1.1 C). None of the debris strikes were seen to damage the launch vehicle. No follow-up action was requested.

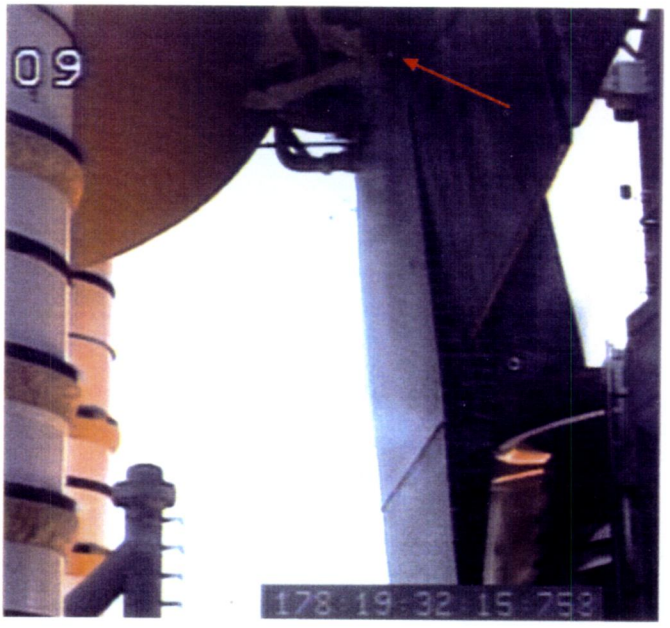



**Figure 2.1.1.1 (A)** Debris Strike to Umbilical Well Door Sill at T-3.2 seconds MET

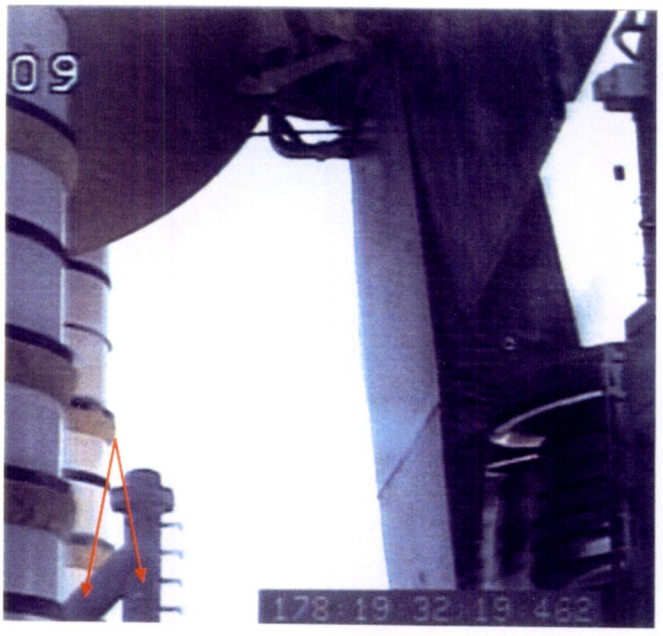



**Figure 2.1.1.1 (B)** Debris Strike to LSRB at 0.4 Seconds MET

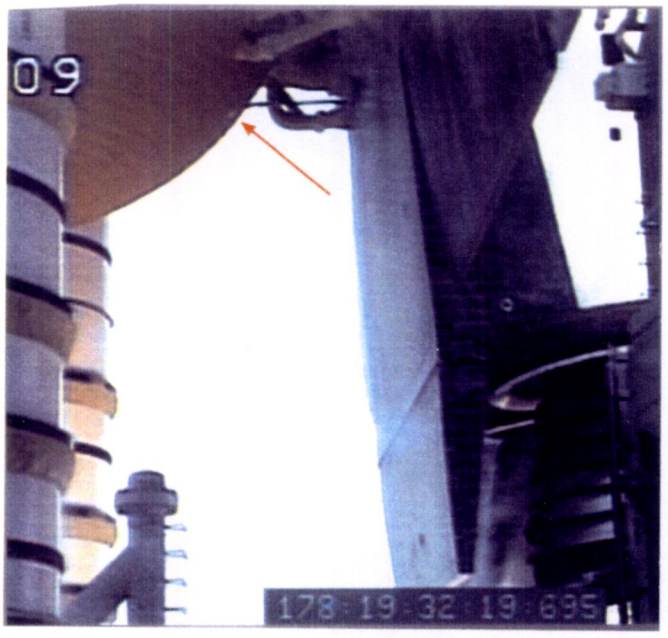



**Figure 2.1.1.1 (C)** Debris Strike to ET Aft Dome at 0.7 Seconds MET

### 2.1.1.2 Debris Near Forward Tip of ET

(Camera: OTV060)

Two small light-colored pieces of debris were seen falling from near the forward tip of the ET at T-14.6 and T-5.8 seconds. The debris was not seen to contact the vehicle. No follow-up action was requested.


**Figure 2.1.1.2** Debris near Forward Tip of ET

### 2.1.1.3 Debris at T-4.1 Seconds MET

(Camera: E5)

A piece of debris was seen near the RSRB. This debris was not seen to contact the vehicle. No follow-up action was requested.

### 2.1.1.4 Dark Debris Near RSRB at T-3.5 Seconds MET

(Camera: E25)


**Figure 2.1.1.4** Dark Debris Near RSRB at T-3.5 Seconds MET

A dark piece of debris was seen moving from the top of the view in front of the RSRB and fell along the underside of the Orbiter. This debris was not seen to contact the vehicle. No follow-up action was requested.

## 2.1.2 Debris Near the Time of SRB Ignition

### 2.1.2.1 SRB Flame Duct Debris

(Cameras: E1, E4, E7 through E16, E26)

More flame duct debris than usual was observed. Two relatively large pieces of flame duct debris were seen beneath the RSRB at 19:32:21.606 UTC (E1). Five pieces of flame duct debris were seen near the RSRB at 19:32:22.300 UTC (E4). No follow-up action was requested.

### 2.1.2.2 LH2 and LO2 Tail Service Mast (TSM) T- 0 Umbilical Disconnect Debris

(Cameras: E17, E18, E19, E20, E76, E77, OTV050, OTV070)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at liftoff. None of the debris was observed to strike the vehicle. No follow-up action was requested.

### 2.1.3 Debris After Liftoff

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 was probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. No follow-up action was requested.

#### 2.1.3.1 Debris at 1.1 Seconds MET
(Camera: E26)


**Figure 2.1.3.1** Debris at 1.1 Seconds MET

A small dark piece of debris was seen falling between the Orbiter and the ET at liftoff. The debris was first seen forward of the ET/Orbiter umbilicals. The debris was not seen to contact the launch vehicle. No follow-up action was requested.

#### 2.1.3.2 Debris at 7 Seconds MET
(Cameras: E57, E223)

Several light-colored pieces of debris were seen falling aft of the vertical stabilizer and the SSMEs. The debris was not seen to contact the vehicle. No follow-up action was requested.

### 2.1.3.3 Debris at 8.3 Seconds MET

(Cameras: E57, E223)

A light-colored piece of debris, first seen near the ET/Orbiter umbilicals, fell aft near the left inboard elevon and the Orbiter fuselage. The debris was not seen to contact the vehicle. No follow-up action was requested.

### 2.1.3.4 Debris at 17.3 Seconds MET

(Cameras: E57, E223 )

A single light-colored piece of debris was seen falling aft of the body flap. The debris was not seen to contact the vehicle. No follow-up action was requested.

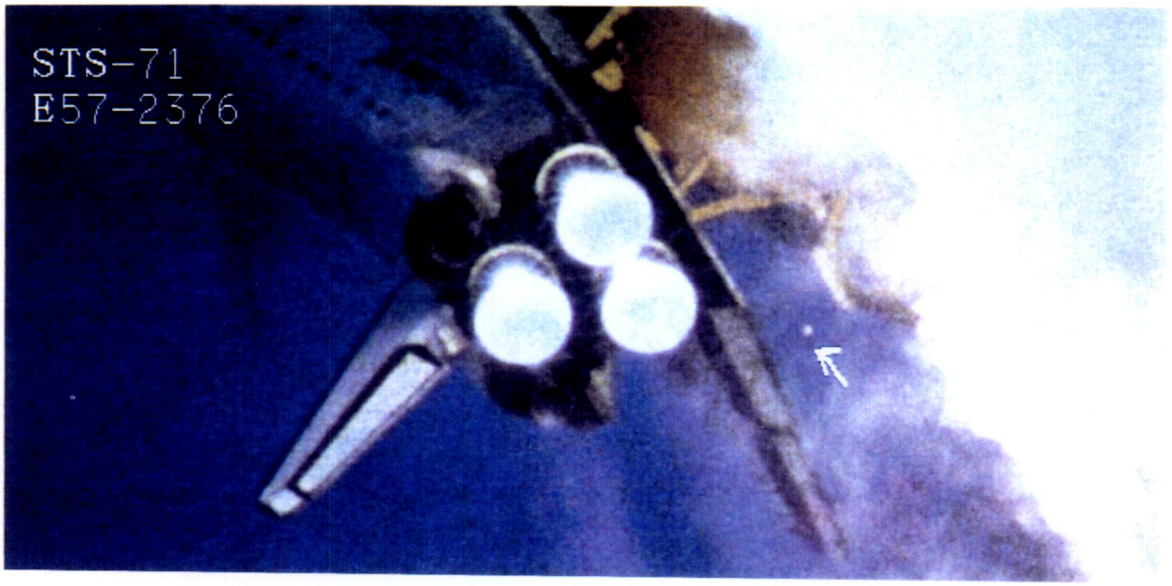



**Figure 2.1.3.4** Debris at 17.3 Seconds MET

### 2.1.3.5 Debris at 23.2, 24.4, and 37.3 Seconds MET

Debris was seen falling aft of the Shuttle Launch Vehicle at 23.2, 24.4, and 37.3 seconds MET. No follow-up action was requested.

### 2.1.3.6 Debris Reported by the Crew (Task #10)

The transcript of the crew debris report is as follows:

*Capcom*::
We have a beautiful view on our GOES Satellite of your plume during ascent. While we have a break right now, we would like any debris report you have.

*Atlantis:*
OK, Kurt. We copied most of that, you got scratchy in the middle of it though. I understand that the Standard Operating Procedure (SOP) is sending regards. By the way of debris Kurt, we really don't see much at all. In the second stage, we saw about four chunks of something that looked kind of like frost I guess, over by the pilot's windows. Charlie has a little bit of smudging that he got on his forward windscreen and that's about it. I would call it essentially nonexistent debris.

*Capcom:*
OK Atlantis, we copy that.

## 2.2 MOBILE LAUNCH PLATFORM (MLP) EVENTS

### 2.2.1 Dark Orange Vapor from R2U RCS Thruster

(Camera: E19)

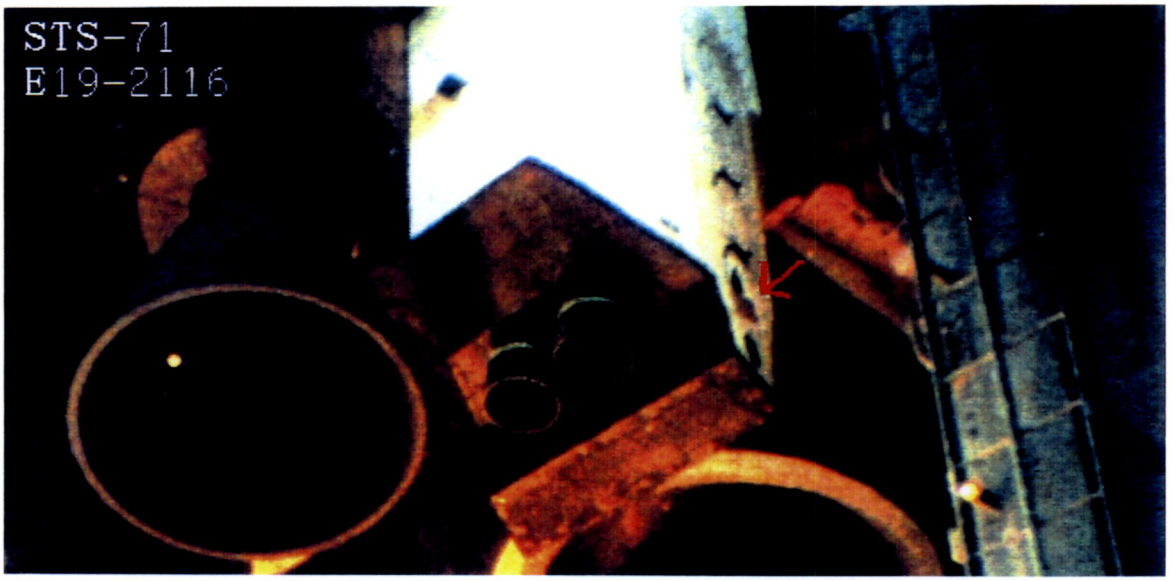



**Figure 2.2.1** Dark Orange Vapor Coming from R2U RCS Thruster

Dark orange-colored vapor was seen coming from the R2U RCS thruster when its paper cover tore during SSME ignition (T-4.5 seconds). KSC reported these vapors to be oxidizer vapors and stated further that this thruster had exhibited signs of a very small leak prior to launch. No follow-up action was requested.

### 2.2.2 Orange Vapors
(Camera: E20)

Orange vapors (possibly free burning hydrogen) were seen rising above the rims of SSME's #1 and #2 at SSME ignition. Orange vapors at SSME ignition have been seen on previous mission launch films and videos. No follow-up action was requested.

### 2.2.3 Vapors from ET/SRB Cable Tray
(Cameras: E34, E35)

Vapors were seen coming from the -Y ET/SRB strut cable tray drain hole at liftoff. KSC reported that this was an expected occurrence due to the humid atmospheric conditions at the time of launch. No follow-up action was requested.


**Figure 2.2.3** Vapors Coming from ET/SRB Strut Cable Tray Drain Hole

### 2.2.4 RCS Cover Tear
(Camera: E40)

An RCS cover (paper) tear was seen on the F3L thruster at liftoff. No follow-up action was requested.

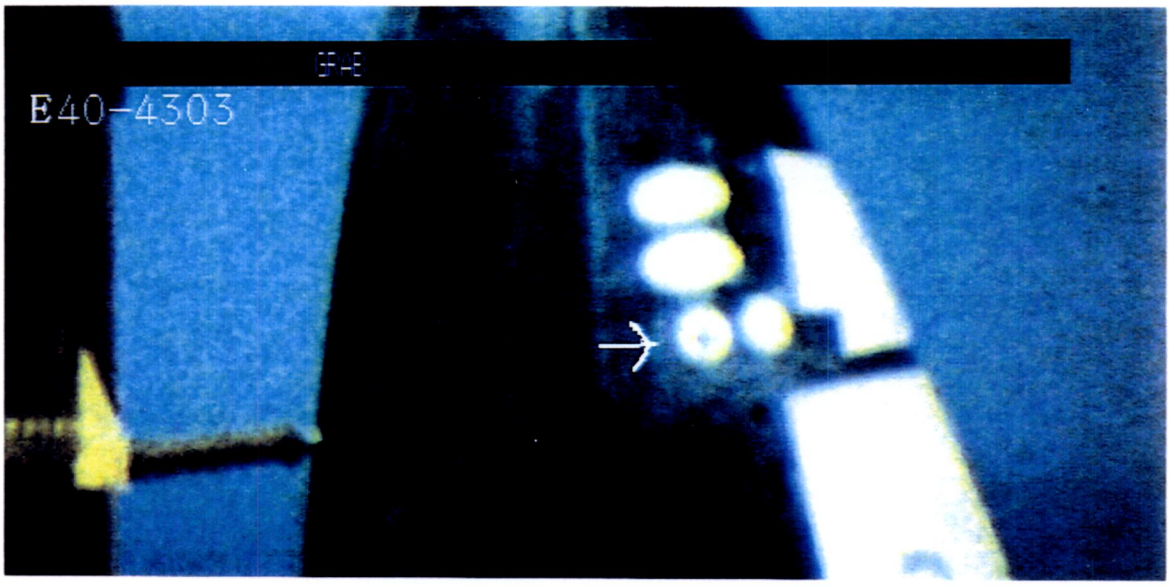



**Figure 2.2.4** RCS Cover Tear on F3L Thruster at Liftoff

### 2.2.5 Erosion of Base Heat Shield Tile Surface Coating Material
(Cameras: E17, E18)

Erosion of the tile surface coating material was seen on the base heat shield and the bases of the right and left RCS stingers at SSME ignition. No follow-up action was requested.

### 2.2.6 Missing Tile Surface Coating Material on Body Flap

(Camera: E76)

Several small areas of tile surface coating material appeared to be missing from the +Z side of the body flap (near SSME #3) at liftoff. No follow-up action was requested.

KSC reported in their post landing inspection report that numerous tile damage sites on the +Z side of the body flap outboard of SSME #3 corresponded to sites identified in the launch film review and were caused by SSME ignition vibration/acoustics.

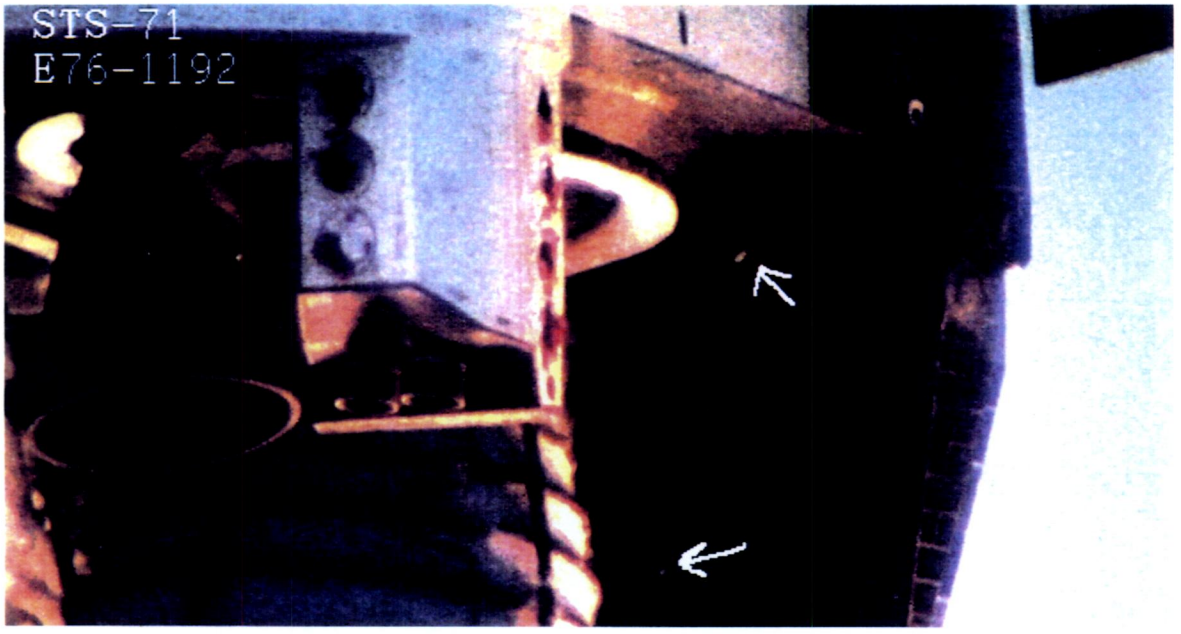



**Figure 2.2.6** Tile Surface Coating Material Missing on +Z Side of Body Flap

### 2.2.7 Surface Discoloration on ET Nose Cone

(Camera: E40)

Several small areas of surface coating material appeared to be discolored or missing on the ET nose cone at liftoff. KSC reported that topcoat, which had adhered to the GOX vent seal during hood retraction, was missing from several areas of the nose cone footprint area. No follow-up action was requested.

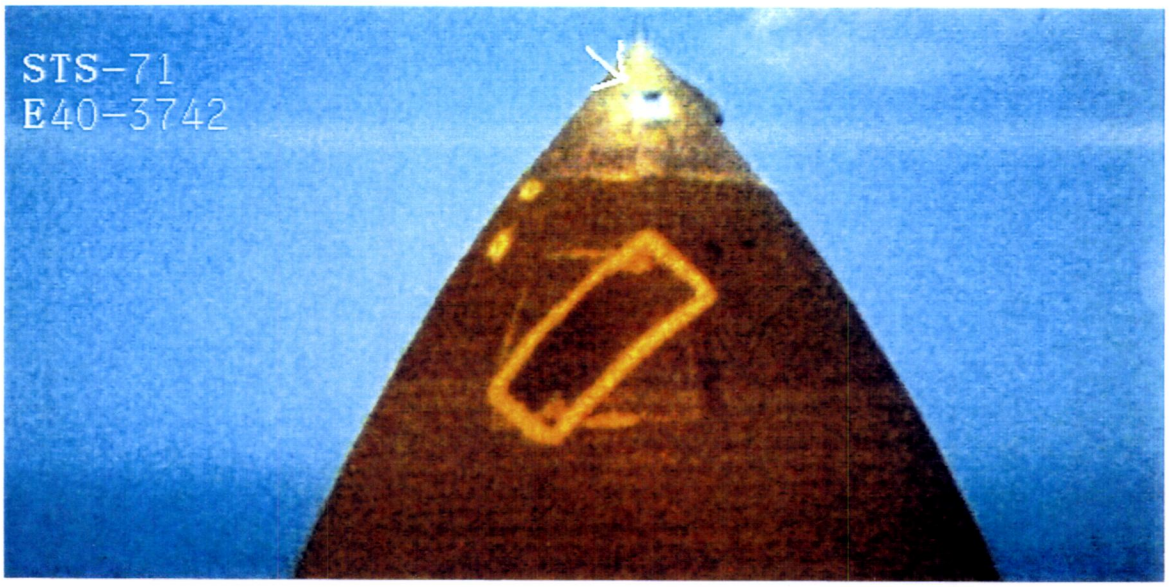



**Figure 2.2.7** Surface Discoloration on ET Nose Cone

### 2.2.8 Flexing of the Orbiter Base Heat Shield

(Camera: E76)

Flexing of the Orbiter base heat shield was seen between the SSME cluster at SSME ignition. Flexing of the base heat shield has been seen on previous missions. No follow-up action was requested.

### 2.2.9 Flashes in SSME Plumes after SSME Ignition

(Cameras: E2, E20, E52)

An orange flash was seen in the SSME #1 exhaust plume at T-2.4 seconds (Cameras: E2, E20). An orange flash was seen in the SSME #3 exhaust plume at T-2.2 seconds (Cameras: E2, E20). Two orange colored flashes were seen in the SSME #1 exhaust plume prior to liftoff (T-1.0 and T-0.5 seconds) (Camera: E52). Orange flashes in the SSME exhaust plumes have been seen on previous missions. No follow-up action was requested.

### 2.2.10 SSME Mach Diamonds Formed Out of Sequence

(Cameras: E76, E78, OTV051, OTV071)

The SSME Mach diamond on SSME #1 formed slightly before the Mach diamond for SSME #2. Normally Mach diamonds form in the sequence SSME #3, SSME #2, and SSME #1. A variation in the sequence of Mach diamond formation was seen on mission STS-59 where the Mach diamond sequence was SSME #2, SSME #1, SSME #3. No follow-up action was requested.

STS-71 Mach Diamond Formation Times:
19:32:15.665 UTC - Mach diamond formation noted in SSME #3
19:32:15.878 UTC - Mach diamond formation noted in SSME #1
19:32:15.908 UTC - Mach diamond formation noted in SSME #2

### 2.2.11 Flash of Light below RSRB Aft Skirt at 0.1 Seconds MET

(Cameras: OTV041, OTV048, OTV063, E60)

A reflection or flash of light was seen below the RSRB aft skirt and reflecting off the base of the ET at 0.1 seconds MET. No follow-up action was requested.

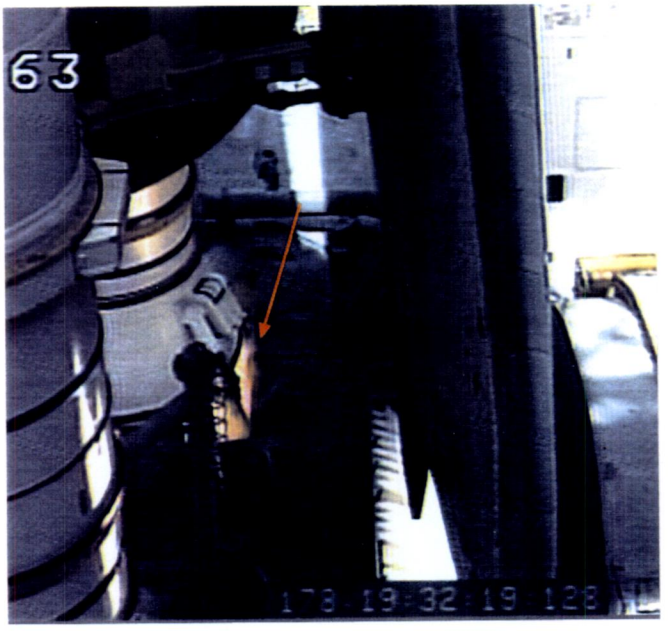



**Figure 2.2.11** Flash of Light below RSRB Aft Skirt at 0.1 Seconds MET

## 2.3 ASCENT EVENTS

### 2.3.1 White Stream off Wing Tip
(Camera: ET207)

A white stream, possibly a contrail, was seen originating form near the Orbiter starboard wing tip at 17.3 seconds MET. No follow-up action was requested.

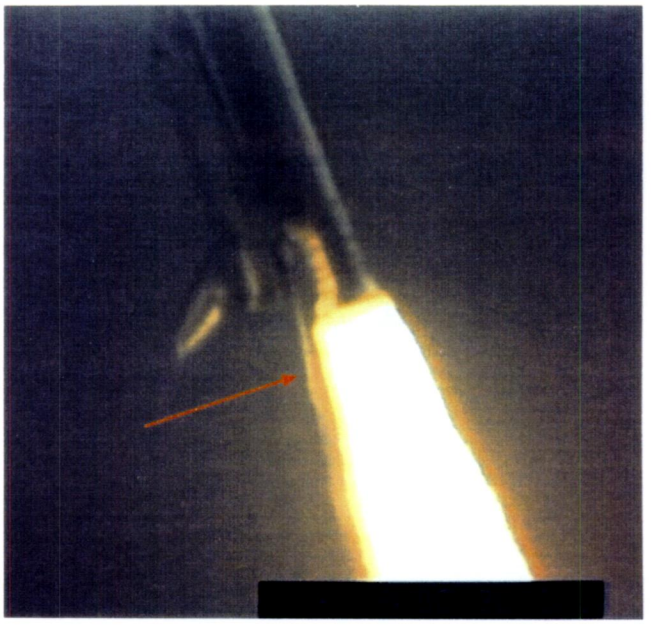


**Figure 2.3.1** White Stream off Wing Tip

### 2.3.2 Body Flap Motion (Task #4)
(Cameras: E17, E18, E207)

As part of an ongoing study of body flap motion on shutttle missions, film cameras E17, E18, and E207 were reviewed to measure body flap motion on the launch pad and during ascent. The motion did not appear to be significant compared to earlier missions and did not warrant further measurements.

### 2.3.3 Flares in SSME Exhaust Plume
(Cameras: E207, E222, E223)

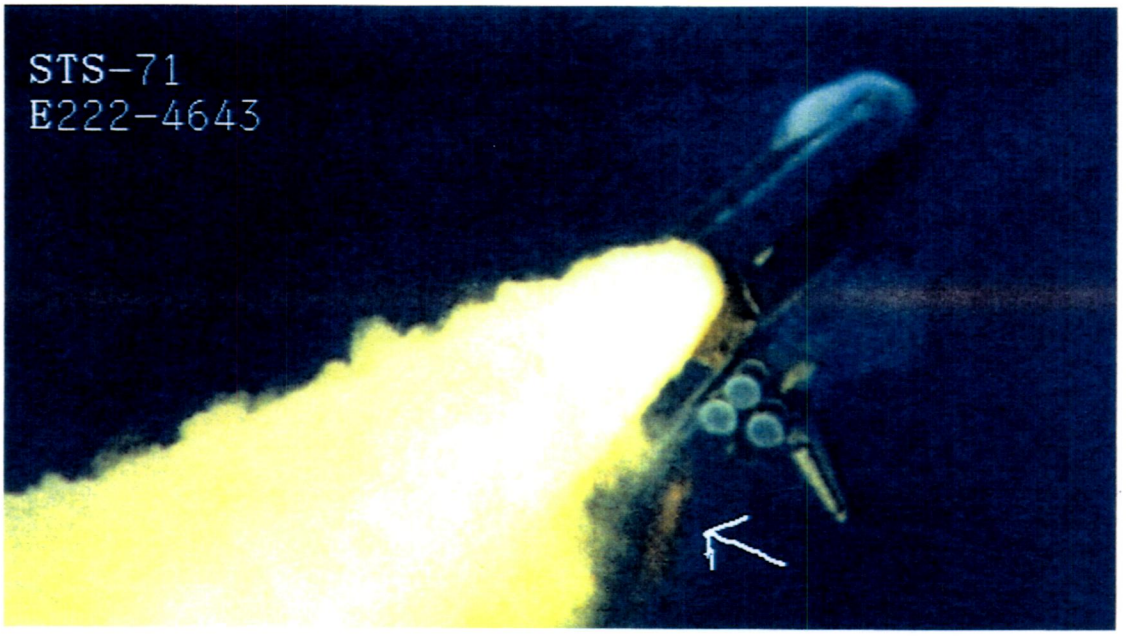



**Figure 2.3.3** Flare in SSME Exhaust Plume

Orange-colored flares were seen in the SSME exhaust plume after liftoff (24.2, 25.6, 42.6, and 42.8 seconds MET) (E223). The flare at 42.6 seconds MET was also seen on E222 (picture above). An orange-colored flare was seen in the SSME exhaust plume at 44.7 seconds MET (E207). No follow-up action was requested.

### 2.3.4 Linear Optical Effects
(Cameras: E212, E218 and KTV13)

Multiple linear optical effects were seen after the roll maneuver. Engineers at the JSC have previously attributed this event to the manifestation of shock waves around the SLV. No follow-up action was requested.

### 2.3.5 Recirculation (Task #1)
(Camera: E205)

The recirculation or expansion of burning gases at the aft end of the Shuttle Launch Vehicle (SLV) prior to SRB separation has been seen on nearly all previous missions. For STS-71, the start of recirculation was observed at approximately 95.4 seconds MET and the end was noted at approximately 105.1 seconds MET. No follow-up action was requested.

### 2.3.6 Vapor-like Object along Exhaust Plume
(Camera: TV13)

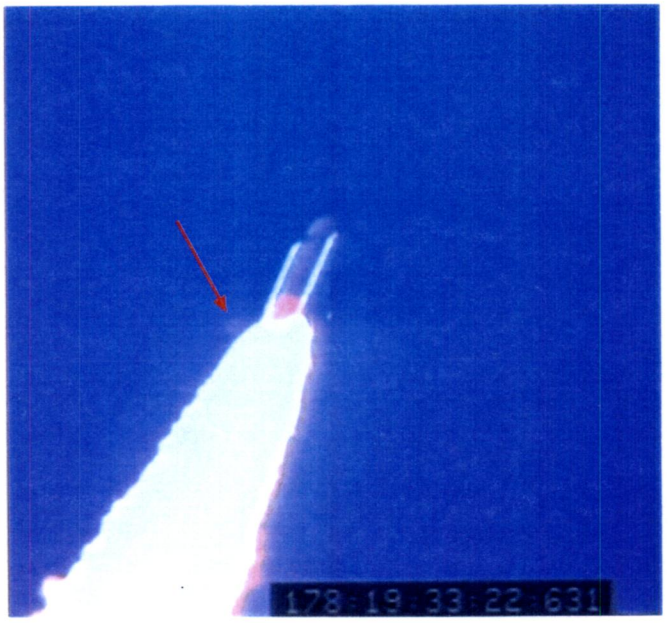



**Figure 2.3.6** Vapor-like Object along Exhaust Plume

A vapor-like object, first seen near the right side of the SLV, fell aft along the SRB exhaust plume at 63.5 seconds MET.

## 2.4 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

### 2.4.1 Analysis of the Umbilical Well Camera Films (Task # 5)

Three rolls of STS-71 umbilical well camera film were received at JSC: the 35 mm film from the LO2 umbilical and two 16 mm films (5 mm lens and 10 mm lens) from the LH2 umbilical.

The 16 mm films have good to dark exposures and good focus. The 35 mm umbilical well film of the ET separation has good to dark exposure and good focus. The ET was back lit by the sun which degrades the views. Timing data was present on the 16 mm films. Timing data was not present (or expected) on the 35 mm film.

The +X translation maneuver was not performed on STS-71.

Numerous light colored pieces of debris (probably insulation) are in view throughout the SRB film sequence. Typical chipping and erosion of the electric cable tray are visible. Erosion and charring of the ET/LSRB aft attach is also visible. A blistering of the fire barrier coating on the outboard side of the LH2 umbilical is apparent. Multiple pieces of white debris (frozen hydrogen) are visible throughout the ET separation sequence. These events are typical of those seen on previous mission umbilical well camera views.

Multiple pieces of debris coming from behind the electric cable tray were visible before and after SRB separation. Debris coming from behind the electric cable tray has been seen on previous mission umbilical well camera views.

The following items were seen on the umbilical well films:

35 mm LO2 Umbilical Film Screening:

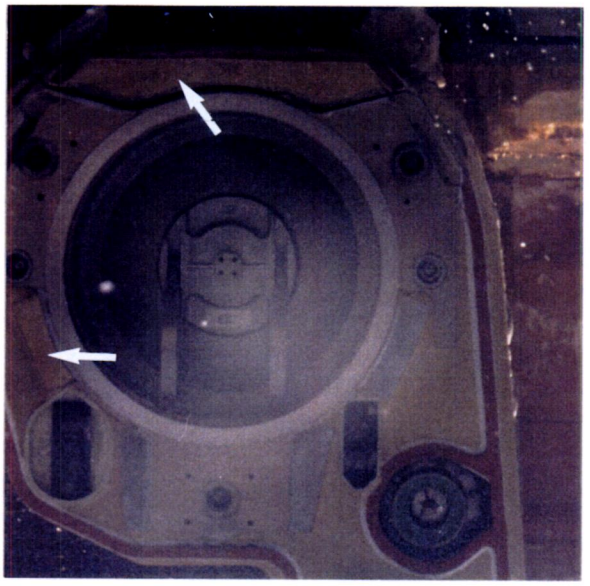


**Figure 2.4.1 (A)** Missing Lightning Contact Strips

The lightning contact strip at the 12 o'clock position forward of the LO2 17 inch line (orifice) is missing. A second contact strip was missing at the 8 o'clock position (Figure 2.4.1 A). LO2 umbilical lightning contact strip(s) were noted missing on STS-57, STS-58, STS-65, STS-66, and other previous mission umbilical well films.

Multiple TPS erosion marks and voids were noted on the LH2 tank TPS in the -Y direction from the aft LO2 feed line support bracket just forward of the cross beam.

**Figure 2.4.1 (B)** Irregular Shaped Debris

An irregular shaped piece of debris which appeared to be dark on one side and light on the other (not ice), was visible in frames 19 - 24 (Figure 2.4.1 B). KSC stated that this debris may be a piece of foam, possibly from the intertank area.

TPS erosion and voids are were noted on the LO2 feed line bellows, support brackets, and the +Y thrust strut.

Several small white debris objects were noted through out the film sequence. Theses white debris objects appear to be frozen hydrogen.

Frost was noted on the aft LO2 feedline attach bracket.

Note: Light reflections were visible through out the entire film sequence. The presence of the red seal around the EO-3 fitting was confirmed. The 35 mm umbilical well film ended prior to the imaging of the ET intertank.

16 mm LH2 Umbilical Well Film Screening ( 5 mm & 10 mm Lenses):

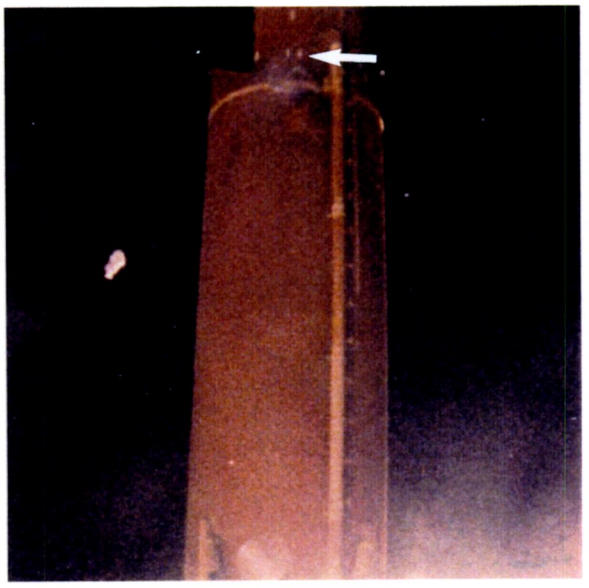


**Figure 2.4.1 (C)** Eight White Marks (Probably Divots)

Approximately eight white marks, probably divots, are visible on the ET intertank TPS forward of the bipod. Four of the marks are linear shaped and are at least eighteen inches in length (Figure 2.4.1 C).

**Figure 2.4.1 (D)** Strap-like Debris

A strap-like piece of debris was seen coming from behind the electric cable tray during ET structural separation (Figure 2.4.1 D). KSC stated that the strap-like object was probably white RTV.

A dark and irregular shaped piece of TPS was seen to detach from the ET/LSRB aft attach prior to SRB separation. This debris broke apart as it fell aft.

An unidentified linear shaped piece of debris, possibly frozen hydrogen, was seen falling away from the base of the ET prior to ET structural separation.

An unidentified somewhat circular piece of debris was seen moving from the left side of view towards the external tank prior to ET separation.

Frozen hydrogen is visible in the orifice of the LH2 umbilical 17 inch line connect after ET separation.

Note: The presence of the red seal around the EO-2 fitting was confirmed.

## 2.5 LANDING EVENTS

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

The main gear sink rate of the Orbiter was determined over a one second time period prior to main gear touchdown. Also, the nose gear sink rate was determined over a one second time period prior to the nose gear touchdown.

The measured main gear and nose gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-71 Orbiter was reported to be 216,372 lbs.). The sink rate measurements for STS-71 are given in Table 2.5.1. In Figures 2.5.1 (A) and 2.5.2 (B), the trend of the measured data points for both film camera image data and video image data are illustrated.

| Prior to Touchdown (1 sec) | Sink Rate: Film | Sink Rate: Video |
|---|---|---|
| Main Gear | 2.1 ft/sec | 3.2 ft/sec |
| Nose Gear | 4.4 ft/sec | 4.6 ft/sec |

**Table 2.5.1:** Sink Rate Measurements

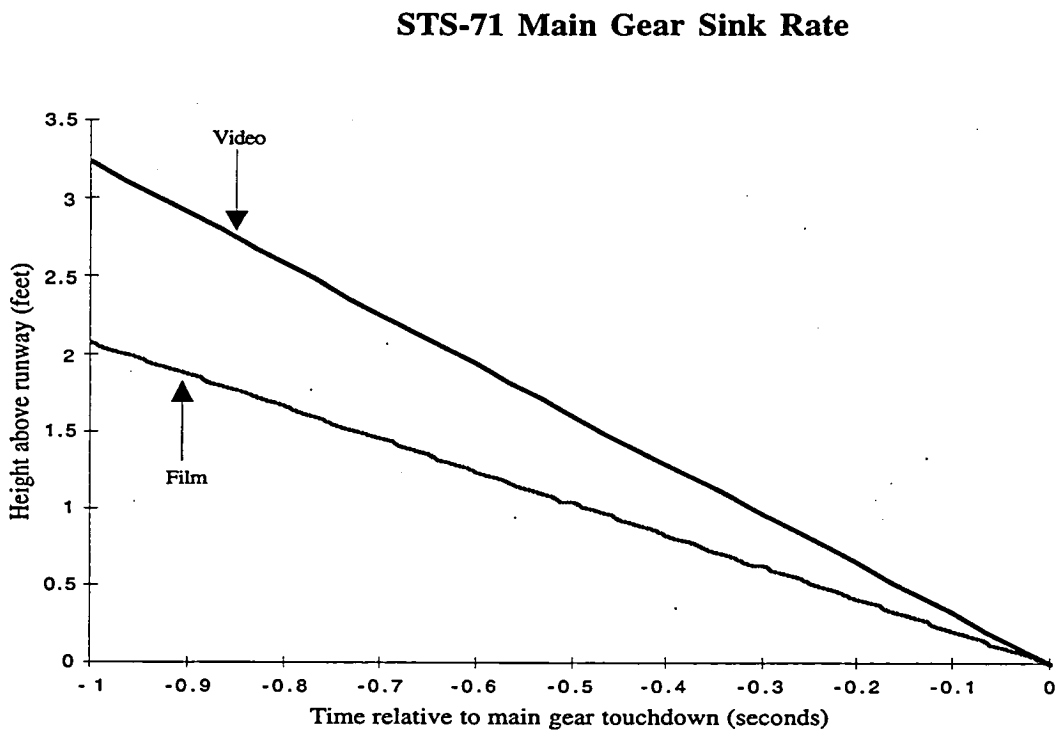



**Figure 2.5.1 (A):** Main Gear Sink Rate from Film (EL7) and Video (KTV33L) (Shown as Trend of Data Points)

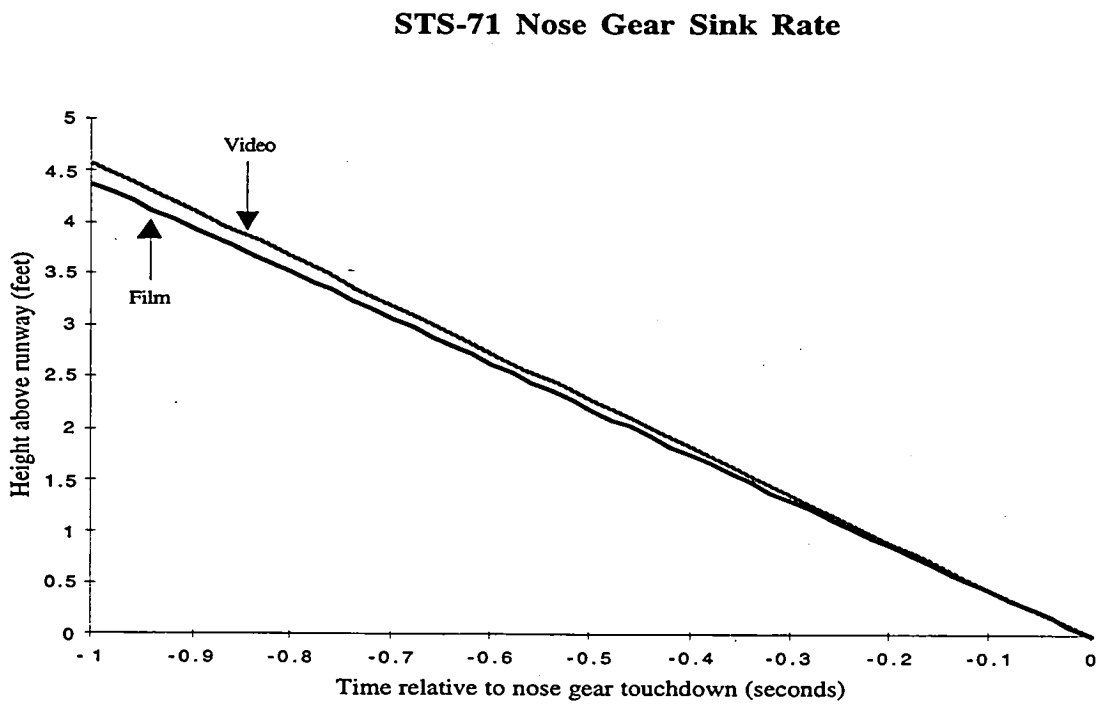



**Figure 2.5.1 (B):** Nose Gear Sink Rate from Film (EL10) and Video (KTV33L) (Shown as Trend of Data Points)

### 2.5.2 Drag Chute Performance (Task #9)
(Camera: E7)

The performance of the drag chute during rollout of STS-71 appeared normal. Film camera EL7 was used to measure drag chute performance. Points taken from EL7 were 1) tip of vertical stabilizer, 2) drag chute center (DCC), 3) left wing tip, and 4) right wing tip. The data points were collected for the time period from drag chute full inflation, reefed configuration, through chute release.

This analysis is used to support the improvement of the aerodynamic math models currently in use. Figure 2.5.2 (A) presents the measured heading angle versus time. Figure 2.5.2 (B) presents the measured riser angle versus time. The maximum measured horizontal chute deflection (heading angle) was approximately 6.7 degrees to the starboard side of the vehicle. The vertical chute deflection (riser angle) ranged from -9 to +0.7 degrees relative to the Orbiter coordinate system.

| Event Description | Time (UTC) | Camera |
|---|---|---|
| Drag Chute Initiation | 188:14:54:38.741 | KTV15 |
| Pilot Chute Inflation | 188:14:54:39.581 | KTV33 |
| Drag Chute - Reefed | 188:14:54:41.366 | KTV33 |
| Drag Chute - Disreefed | 188:14:54:44.603 | KTV33 |
| Drag Chute Release | 188:14:55:09.177 | KTV33 |

**Table 2.5.2:** Drag Chute Event Times

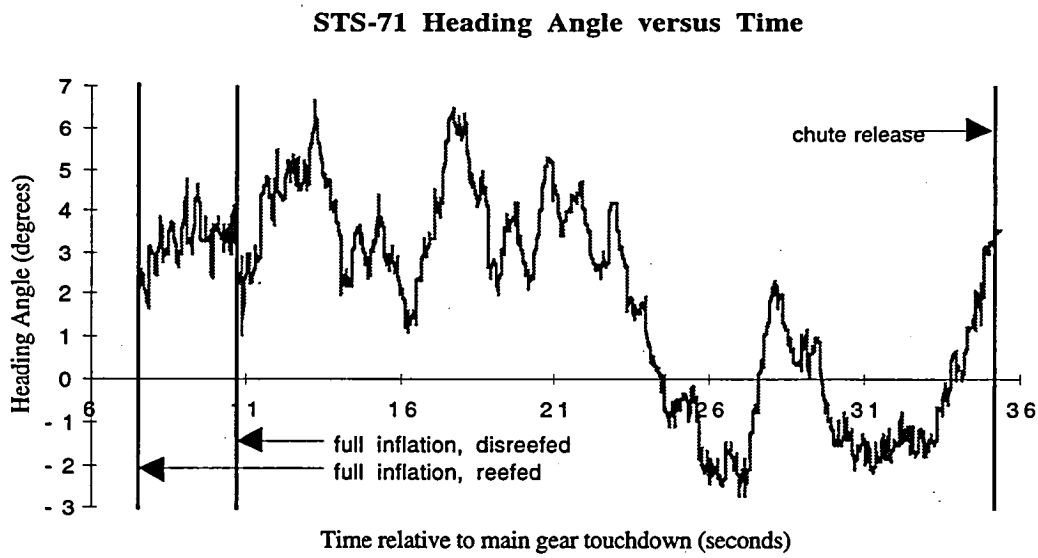



**Figure 2.5.2 (A):** Drag Chute Heading Angle versus Time

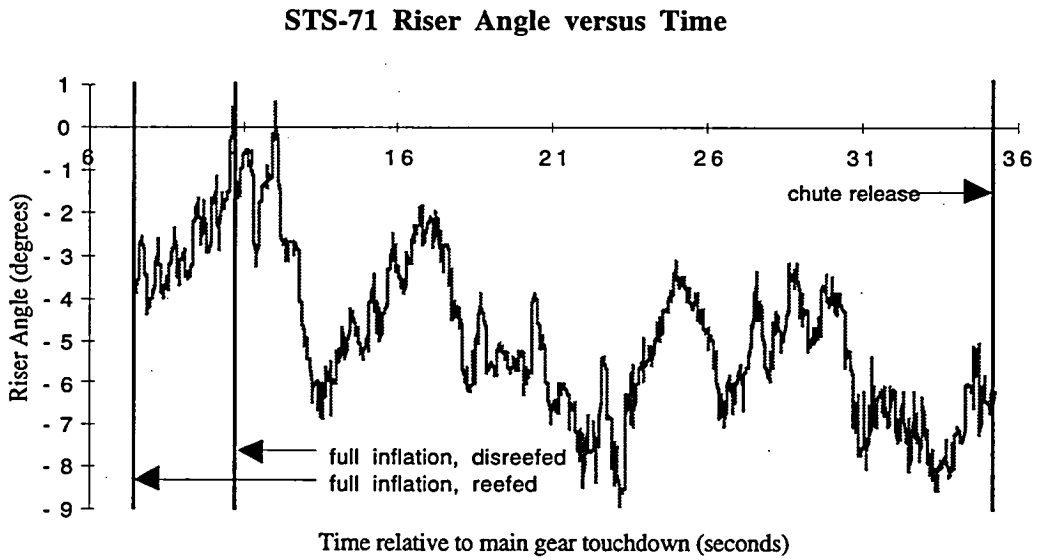



**Figure 2.5.2 (B):** Drag Chute Riser Angle versus Time

### 2.5.3 Orbiter Height above Threshold (Task #13)

The Orbiter height above threshold for STS-71 was measured to be a distance of 17.9 feet between the bottom of the main gear tire and the runway surface as the Orbiter passed over the runway threshold during final approach. The image resolution and photogrammetric error considerations indicate an error of +/- 4 inches for this measurement.

## 2.6 OTHER

### 2.6.1 Normal Events

Other normal events observed include: slight body flap motion at SSME ignition, RCS paper debris at SSME ignition, debris on/near the MLP between SSME start-up through liftoff, elevon motion prior to liftoff, vapors from the ET vent louvers prior to liftoff, a bird in the vicinity of the Shuttle Launch Vehicle at liftoff, ET twang, vapor and ice from the GUCP area during ET GH2 vent arm retraction, acoustic waves in the exhaust cloud at liftoff, debris in the exhaust plume at liftoff, slight motion of the vertical stabilizer and left wing at liftoff, RCS paper debris during liftoff, vapor from SRB stiffener rings after liftoff, ET aft dome outgassing and charring after liftoff, expansion waves after liftoff, condensation around the Shuttle launch vehicle after the roll maneuver, linear optical effects after the roll maneuver, SRB plume brightening prior to SRB separation, dark puffs in the SRB plume prior to SRB separation, SRB separation, and debris in the SRB exhaust plumes after SRB separation.

Normal events related to the pad are hydrogen ignitor operation, mobile launch platform (MLP) deluge water activation, fixed service structure (FSS) deluge water activation, GH2 vent arm retraction, and sound suppression water activation.

# APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

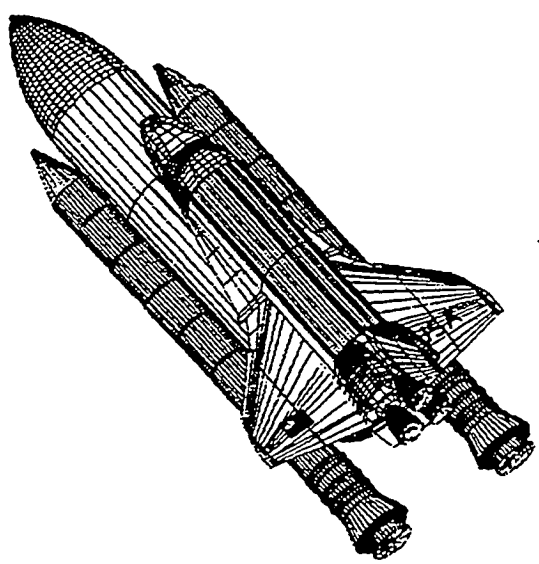
National Aeronautics and
Space Administration

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

# SPACE SHUTTLE

# ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

# STS-71



# ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

## STS-71

FINAL

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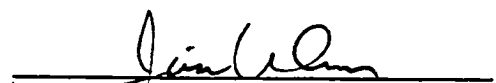

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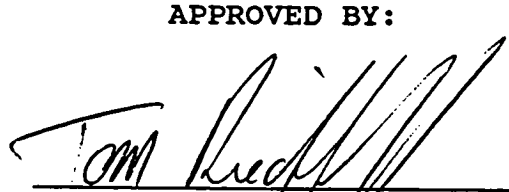

T. RIECKHOFF, MSFC/EP24
B. LINDLEY-ANDERSON, MSFC/EP24

STS-71 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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July 24, 1995

## I. INTRODUCTION

The launch of space shuttle mission STS-71, the fourteenth flight of the Orbiter Atlantis occurred on June 27, 1995, at approximately 2:32 P.M. Central Daylight Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida.

Extensive photographic and video coverage exists 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 the vehicle, and uprange and downrange tracking sites.

## II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-71 included, but were not limited to the following:

a. Overall facility and shuttle vehicle coverage for anomaly detection
b. Determination of SRB PIC firing time and SRB separation time
c. Verification of Thermal Protection System (TPS) integrity
d. Correct operation of the following:
    1. SSME ignition
    2. SRB debris containment system
    3. LH2 and LO2 17" disconnects
    4. Ground umbilical carrier plate (GUCP)
    5. Free hydrogen ignitors
    6. Booster separation motors (BSM)
    7. Vehicle clearances
    8. Vehicle motion
e. Verification of cameras, lighting and timing systems

## III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-two of fifty-three 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-71.

**Camera data received at MSFC for STS-71**

| | 16mm | 35mm | Video |
|---|---|---|---|
| MLP | 22 | 0 | 4 |
| FSS | 7 | 0 | 3 |
| Perimeter | 3 | 3 | 6 |
| Tracking | 0 | 14 | 11 |
| Onboard | 2 | 1 | 0 |
| **Totals** | 34 | 18 | 24 |

Total number of films and videos received: 76

The individual motion picture and video camera assessments are available on the Engineering Photographic Analysis server on the World Wide Web. The server address is http://photo4.msfc.nasa.gov/msfc.html

a. Ground Camera Coverage:

Both film and video from ground cameras were of excellent quality. The afternoon launch time provided good lighting conditions. However, cloud coverage obscured the launch vehicle from the long range tracking cameras for a portion of the ascent. No data was received from camera E-54 due to a film jam. The timing on camera E-14 was not set to record UTC time.

b. Onboard Camera Coverage:

On-board film from the umbilical well cameras was received. The orbiter +X translation to move forward over the tank was not performed in order to save propellants.

IV. ANOMALIES/OBSERVATIONS:

While viewing the film, several events were noted which occur on most missions. These events consist of ice/frost falling from the 17 inch disconnects during SSME ignition and launch, 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, glowing debris particles exiting the SRM plumes and slag from the SRM's prior to and during SRB separation.

There were no indications of a holddown post stud hang-up or debris from the explosive bolt fragments.

A flash of light was noted on the right SRB during booster ignition. Figure one is a video frame from camera OTV-048 showing the event.

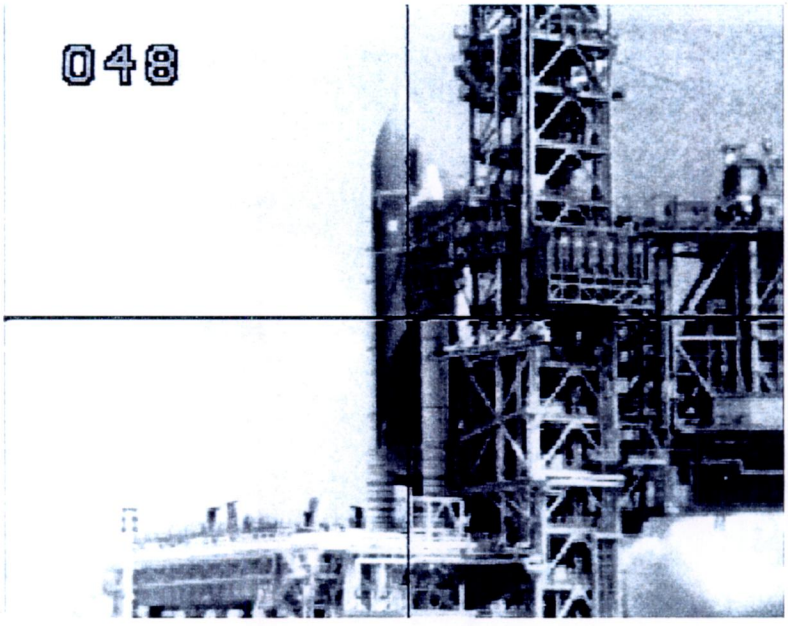


Figure 1 Frame from video camera showing light flash on SRB

Figure two is a frame from camera OTV-048 prior to the event and is used for comparison.

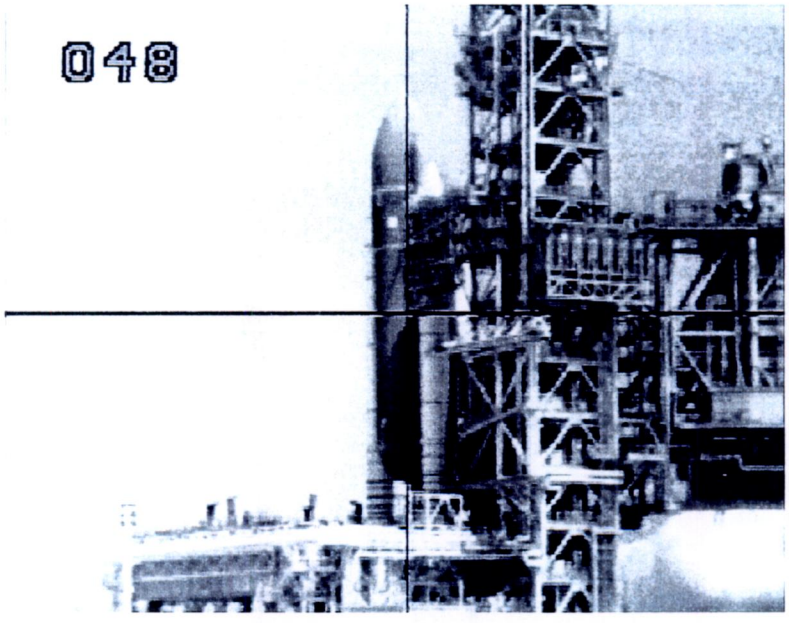


Figure 2 Video frame prior to flash event

These two images were subtracted from each other to show the areas that were illuminated from the flash. This result is shown in Figure three.

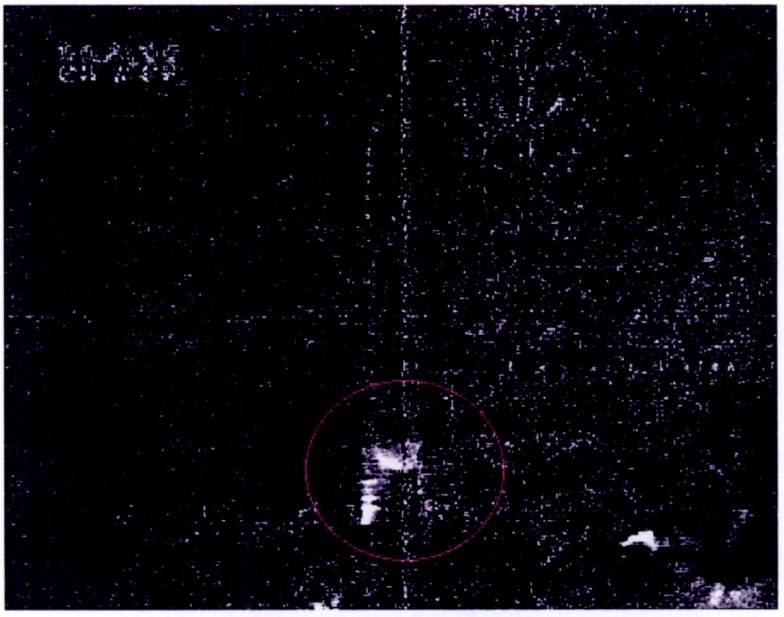

Figure 3 Result of subtraction of video frames

The image in Figure four shows a comparison of video frames of four different launches showing the event described above.

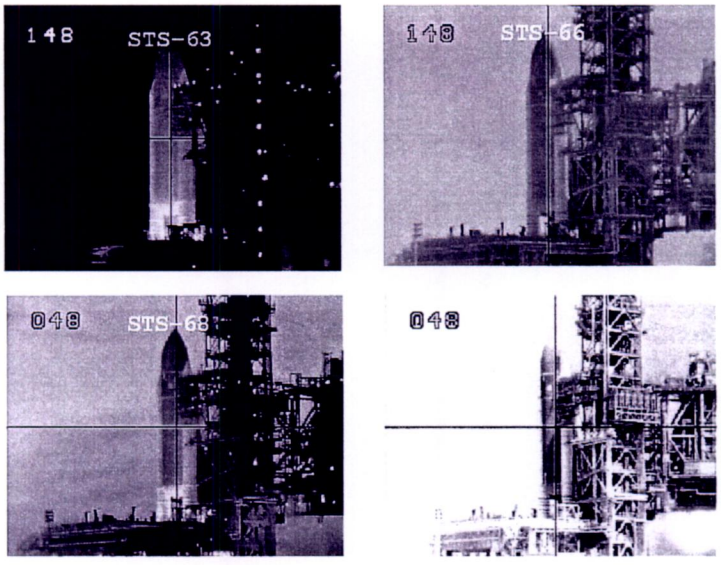


Figure 4 Comparison with other launches

Lighting conditions are a determining factor in whether the flash is discernible in single frame. The flashes are very visible while viewing the video tape.

A somewhat larger amount of debris than normal was noted from the SRB flame ducts during the ignition of the SRB's and vehicle liftoff. Most of this debris appears to be foam and does not strike the vehicle. One of the larger debris objects is depicted in Figure five taken from camera E-11.

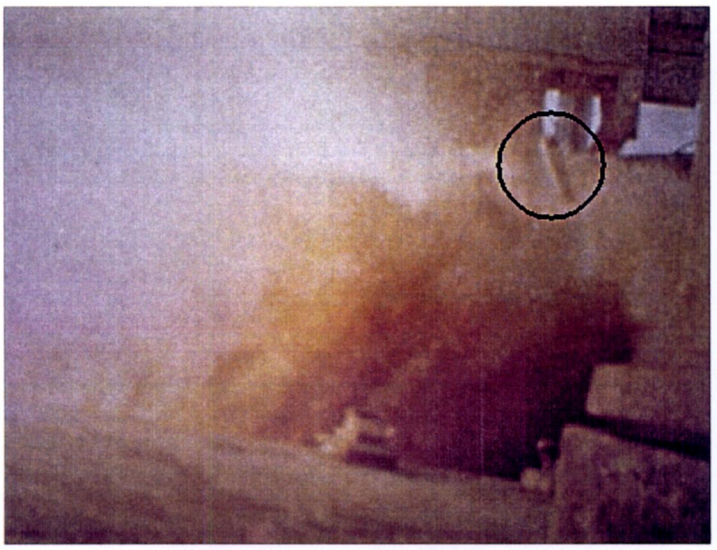

Figure 5 Large debris object from SRB flame duct

During SSME startup the butcher paper that covers the RCS motors is torn by the acoustic waves created by the main engines. It was noted that a brown colored vapor originated from an RCS motor on the right stinger pod when the butcher paper was torn. Figure six depicts this event and is taken from camera E-19.

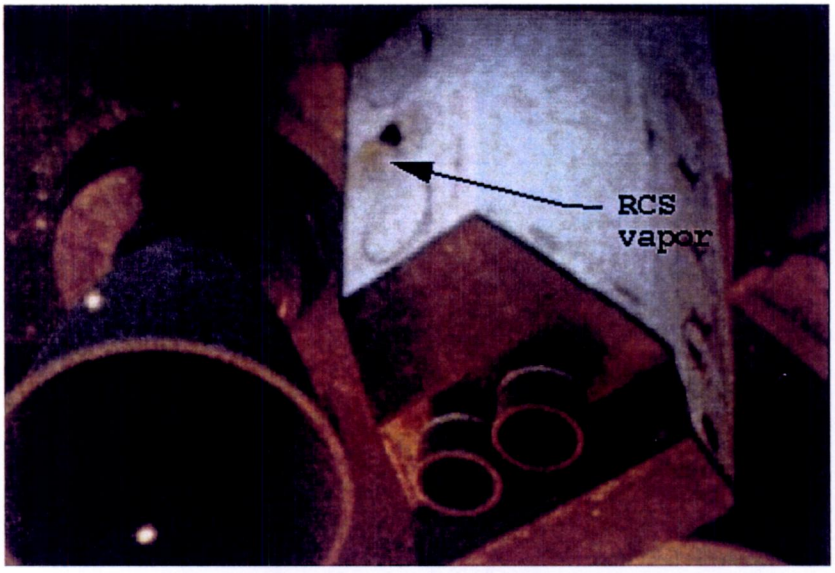


Figure 6 Vapor from RCS motor

During the SSME ignition sequence, the mach diamond on ME-1 forms prior to the mach diamond on ME-2. Figure seven is a film frame taken from camera E-20 showing the mach diamond on ME-1. It can be seen from this image that the mach diamond has not yet formed on ME-2. This situation has occurred before on previous missions and may be a result of the ambient base pressure. Film was reviewed from six previous missions on which this engine

flew in the number 2 position. Only one other episode of a late mach diamond formation was observed. This occurred on STS-60 on which the mach diamond on ME-2 formed 5 milliseonds later than the mach diamond on ME-3.

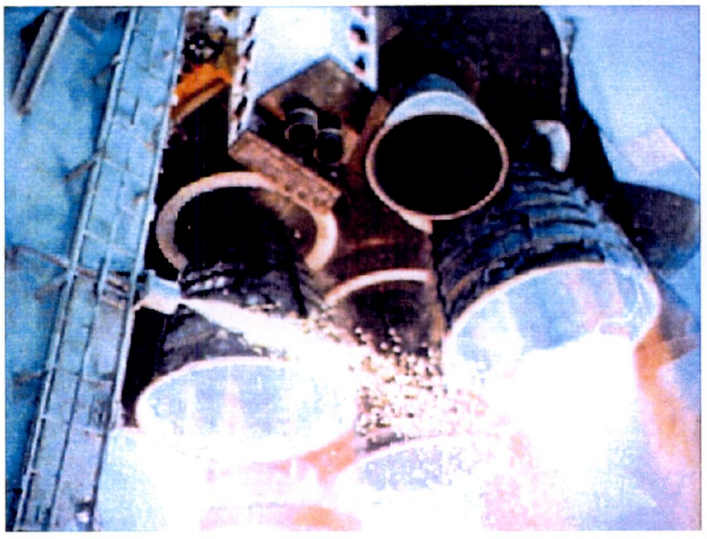

Figure 7 Late mach diamond formation on SSME #2

There were several debris induced streaks noted in the SSME plume during ascent. Figure eight is a frame taken from tracking camera E-222 showing one of the larger of these streaks.

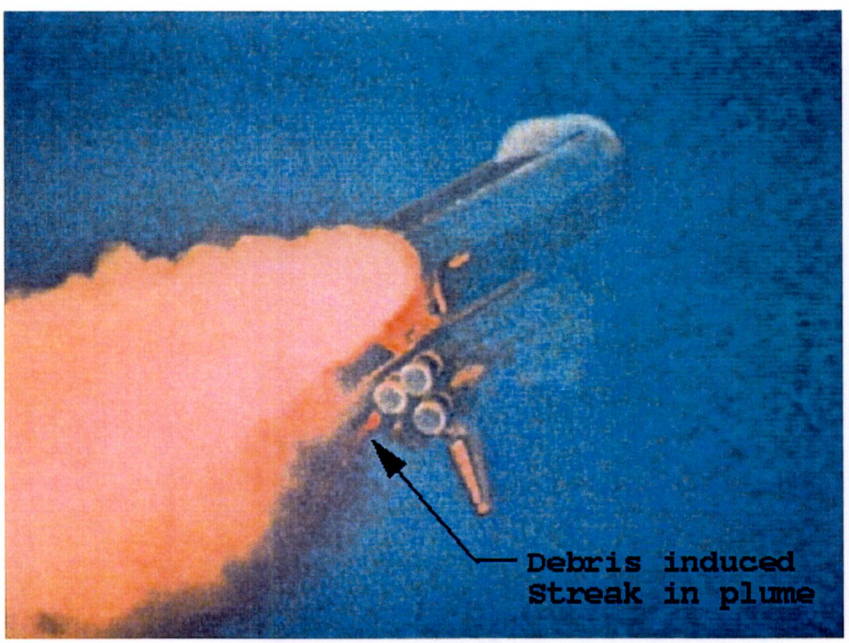


Figure 8 Debris induced streak in SSME plume

The umbilical well films of the external tank revealed TPS divots on the intertank stringers. Additional TPS damage is also visible near the base of the bipod strut. These type

divots have been observed before and corrective measures have been instituted for future tanks effective on ET-74 resulting from an earlier IFA. Figure nine is a film frame from the 16mm umbilical well camera of these divots.

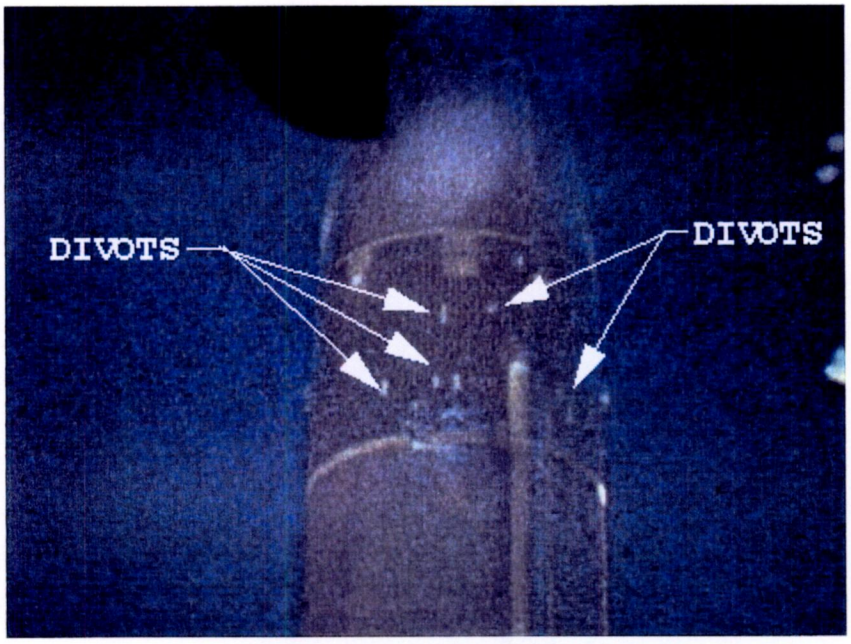


Figure 9 ET TPS divots

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 | 178:19:32:18.996 |
| M-2 | E-8 | 178:19:32:18.996 |
| M-5 | E-12 | 178:19:32:18.997 |
| M-6 | E-13 | 178:19:32:18.998 |

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was measured to be approximately 31 inches. Figure ten is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. A positive horizontal displacement represents motion in the -Z direction. These data were derived from film camera E-79.

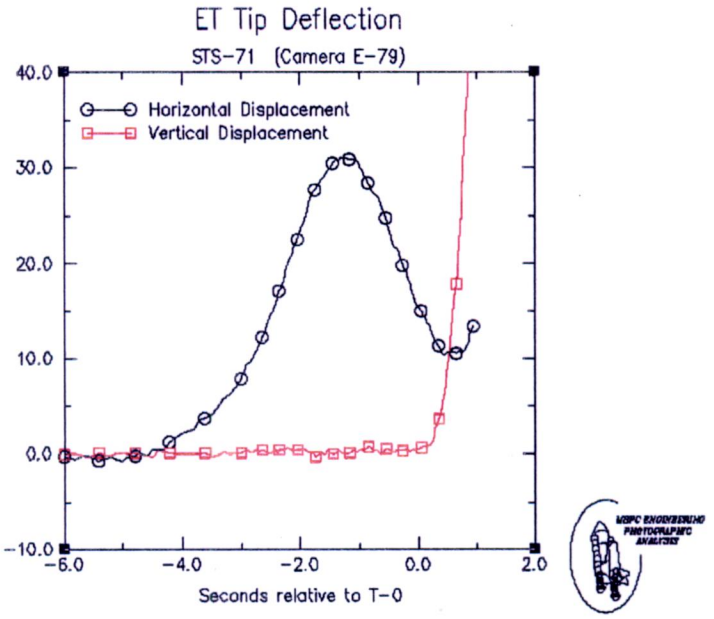


Figure 10 ET Tip Deflection

c. SRB Separation Time:

SRB separation time for STS-71 was determined to be 178:19:34:22.57 UTC as recorded by several tracking cameras.

# REPORT DOCUMENTATION PAGE

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A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-71. 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 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-71 and the resulting effect on the Space Shuttle Program.

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STS-71 Thermal Protection System (TPS)
Ice Debris Photographic Analysis

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