TR/IN/16
2001 092 836

533291
78p

Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle mission STS-102

Jorge E. Rivera

Technical Memorandum – 2001 – 210257 **May 2001**

Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle mission STS-102

Jorge E. Rivera
Processing Engineering/Mechanical System Division/ET-SRB Branch,
Kennedy Space Center, Florida

Technical Memorandum – 2001 – 210257 **May 2001**

DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-102

March 08, 2000

Contributions By:

NASA, United Space Alliance,
Lockheed-Martin, The Boeing Company, and Thiokol Members of the
Debris/Ice/TPS and Photographic Analysis Teams

Approved:

Jorge E. Rivera
Shuttle Ice/Debris Systems
NASA - KSC
Mail Code: PH-H2

Peter Chitko
Chief, ET/SRB Mechanical Branch
NASA - KSC
Mail Code: PH-H2

TABLE OF CONTENTS

TABLE OF CONTENTS I

TABLE OF FIGURES II

TABLE OF PHOTOS III

FOREWORD IV

1.0 SUMMARY OF SIGNIFICANT EVENTS 2

2.0 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION 3

3.0 LAUNCH 4

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION 4
3.2 FINAL INSPECTION 4
3.2.1 ORBITER 4
3.2.2 SOLID ROCKET BOOSTERS 4
3.2.3 EXTERNAL TANK 4
3.2.4 FACILITY 5
3.3 T-3 HOURS TO LAUNCH 5

4.0 POST LAUNCH PAD DEBRIS INSPECTION 11

5.1 LAUNCH FILM AND VIDEO SUMMARY 12
5.2 ON-ORBIT FILM AND VIDEO SUMMARY 15
5.3 LANDING FILM AND VIDEO SUMMARY 15

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT 24

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY ..... A
APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY ..... B

TABLE OF FIGURES

FIGURE 1: ORBITER LOWER SURFACE DEBRIS DAMAGE MAP 26
FIGURE 2: ORBITER UPPER SURFACE DEBRIS DAMAGE MAP 27
FIGURE 3: ORBITER RIGHT/LEFT SIDES DEBRIS DAMAGE MAP 28
FIGURE 4: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY 29
FIGURE 5: CONTROL LIMITS FOR LOWER SURFACE HITS 30
FIGURE 6: CONTROL LIMITS FOR TOTAL HITS 31

TABLE OF PHOTOS

PHOTO 1: LAUNCH OF SHUTTLE MISSION STS-102 1
PHOTO 2: FROST ON LH2 TANK 7
PHOTO 3: LH2 TANK ACREAGE 8
PHOTO 4: ET LO2 TANK FORWARD 9
PHOTO 5: CRACKS IN –Y VERTICAL STRUT 10
PHOTO 8: SRB AFT SKIRT INSTAFOAM MATERIAL BROKE OFF DURING LIFT OFF 14
PHOTO 11: ASTRONAUT HANDHELD CAMERA VIEW OF THE EXTERNAL TANK 16
PHOTO 12: VIEW OF THE EXTERNAL TANK AFTER SEP 17
PHOTO 13: VIEW OF THE EXTERNAL TANK AFTER SEP 18
PHOTO 14: VIEW OF THE EXTERNAL TANK AFTER SEP 19
PHOTO 12: FRUSTUM POST FLIGHT CONDITION 21
PHOTO 13: FORWARD SKIRT POST FLIGHT CONDITION 22
PHOTO 14: SRB POST FLIGHT CONDITION 23
PHOTO 16: OVERALL VIEW OF ORBITER SIDES 32
PHOTO 17: WINDOWS AND BASE HEAT SHIELD 33
PHOTO 18: DAMAGE TO LOWER SURFACE TILES 34
PHOTO 19: R/H OMS POD 35
PHOTO 20: LO2 ET/ORB UMBILICAL 36
PHOTO 21: LH2 ET/ORB UMBILICAL 37

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.

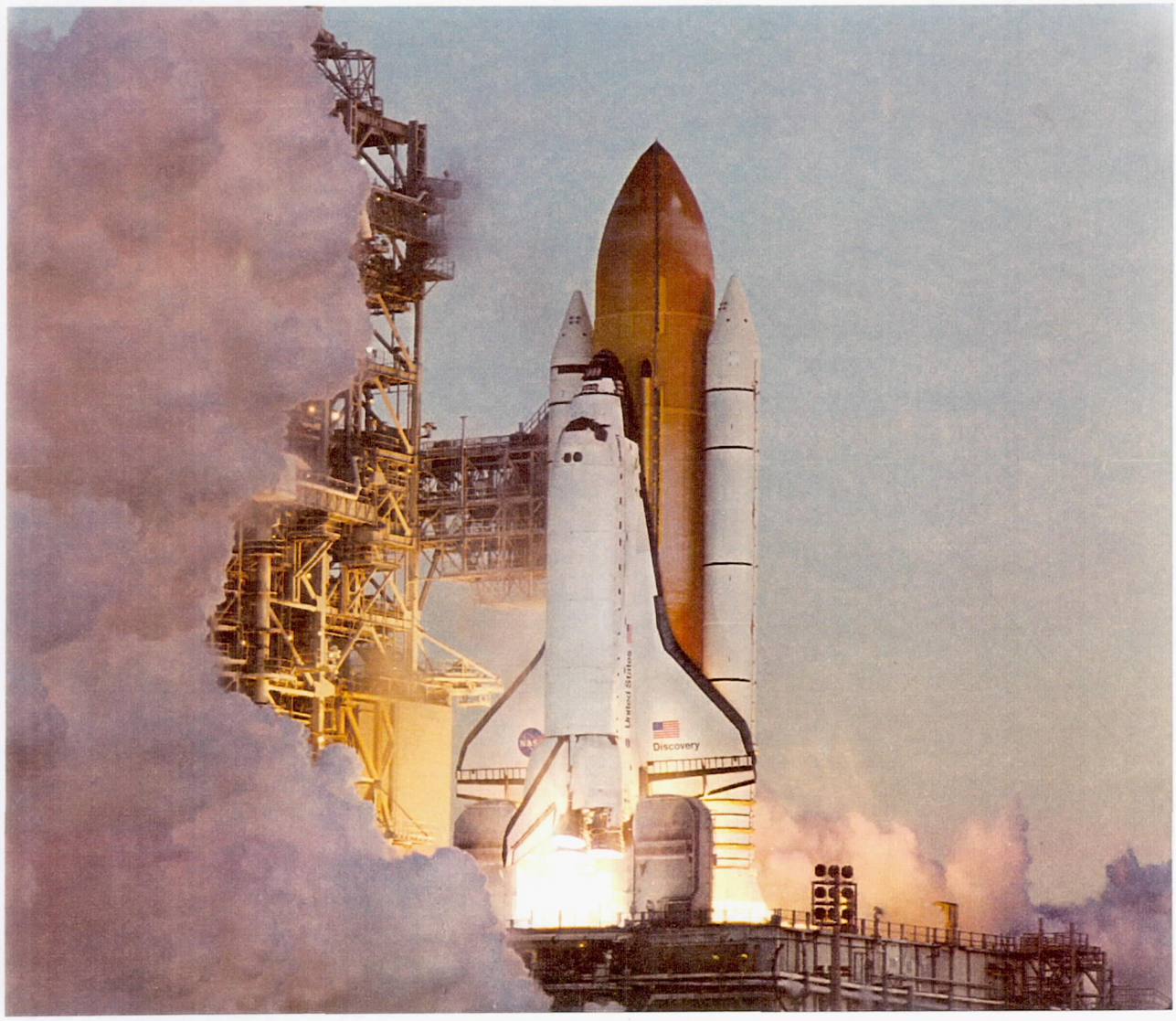


Photo 1: Launch of Shuttle Mission STS-102

1.0 SUMMARY OF SIGNIFICANT EVENTS

STS-102 consisted of OV-103 Discovery (29th flight), ET-107, and BI-106 SRB's on MLP-3 and Pad 39B. Discovery was launched at 067:11:42:09.014 UTC (6:42 a.m. local) on 08 March 2001. Landing was at 2:31 a.m. local/eastern time on 21 March 2001.

No significant anomalous events were noted during STS-102 Debris Team surveillance activities.

The Orbiter lower surface sustained 44 total hits, of which 10 had a major dimension of 1-inch or larger, both numbers are well within family. Approximately 14 damage sites (with two larger than 1-inch in length) were located in the area from the nose landing gear to the main landing gear wheel wells. The majority of the hits were around the LH2 umbilical area (22 hits). Most of these damage sites around the ET/ORB umbilical were most likely caused by pieces of the umbilical purge barrier flailing in the airstream and contacting tiles before pulling loose and falling aft.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were well within established family. ET TPS venting modifications continue to have a reducing effect on the quantity and size of the damage sites.

2.0 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted at 0800 on 07 March 2001. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Rivera	NASA - KSC	ET Mechanisms/Structures
A.Oliu	NASA - KSC	Shuttle Ice/Debris Systems
R. Speece	NASA - KSC	Thermal Protection Systems
B. Nguyen	NASA - KSC	SRB Mechanical Systems
M. Payne	NASA - KSC	SRB Mechanical Systems
R. Page	NASA - KSC	SSP Integration
K. Revay	USA - SFOC	Manager, ET/SRB Mechanical Systems
K. Leggett	USA - SFOC	Supervisor, ET/SRB Mechanical Systems
J. Blue	USA - SFOC	ET Mechanical Systems
W. Richards	USA - SFOC	ET Mechanical Systems
M. Wollam	USA - SFOC	ET Mechanical Systems
T. Ford	USA - SFOC	ET Mechanical Systems
R. Seale	USA - SFOC	ET Mechanical Systems
R. Brewer	USA - SFOC	ET Mechanical Systems
R. Oyer	Boeing	Systems Integration
D. Leggett	Boeing	Systems Integration
B. Atkinson	Boeing	Systems Integration
T. Wilson	Boeing	Systems Integration
S. Otto	LMMSS	ET Processing
J. Ramirez	LMMSS	ET Processing
A. Khodaoust	Boeing	Shuttle Aerodynamics
M. Eastwood	Thiokol-LSS	SRM Processing

3.0 LAUNCH

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 07 March 2001. The walkdown of Pad 39B and MLP-3 included the flight elements OV-103 Discovery (29th flight), ET-107, and BI-106 SRB's. There were no significant SSV discrepancies. All facility items were identified and corrected real time, therefore no potential debris items were entered in OMI S0007 Appendix K for resolution prior to cryoload.

The weather forecast predicted a low of 47 degrees F at L-6 hours (0030 local) along with 71% RH and 10-knot winds at 310 degrees. By T-0, the temperature was expected to be 44 degrees F, 82% RH, and 8-knot winds at 300 degrees. Under these conditions, the computer program SURFICE calculated ET TPS temperature below 32 degrees F during ET cryoload. Also SURFICE predicted positive maximum ice rate that had a potential to accumulate beyond the 1/16-inch maximum ice thickness, attainable only if worst-case moisture (e.g. fog, drizzle, mist runoff) existed. The team advised the Mission Management Team that due to the low humidity frost, no acreage ice would have formed. A contingency plan was developed to send the FIT to the Pad a second time near the T-20 minutes build-in hold if necessary to verify the presence of ice. Based on this rationale no constraint was given for tanking.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 08 March 2001 from 0030 to 0245 hours during the two-hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC) or OMRS criteria violations. There was no acreage icing concerns. There were also no protuberance icing conditions outside of the established database.

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

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The RCS thruster paper covers were intact without any visible discoloration. Ice/frost had formed on the SSME #1 and #2 heat shield-to-nozzle interfaces.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers were close to ambient temperatures. All measured temperatures were above the 34 degrees F minimum requirement.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a comparison to infrared scanner point measurements. The program predicted below freezing temperatures and frost during ET cryoload. The following table shows ambient condition, SURFICE prediction and IR surface temperatures at the start of FIT walkdown.

Ambient conditions – 0030hrs	SURFICE Predictions	IR Surface Readings
47.8 Degrees F.	LO2 ogive 32.77 Degrees F	LO2 Tank 36 – 41 Degrees F
71% RH	LO2 barrel 25.69 Degrees F	
6.3 knots	LH2 upper 21.25 Degrees F	LH2 Tank 32 – 40 Degrees F
266.8 degrees	LH2 lower 32.38 Degrees F	

The Final Inspection Team observed no condensate on the LO2 tank acreage with some patches of frost on the barrel section (+Y/+Z side). Surface temperatures ranged from 32 to 41 degrees Fahrenheit. There were no TPS anomalies.

No significant anomalies were present in the intertank TPS. A total of four cracks in the intertank stringer valley TPS were observed (-Y/-Z side and –Y/+Z side). Neither cracks exhibited ice, frost, nor offset. Therefore, the cracks were acceptable for flight per the NSTS-08303 criteria. Ice and frost accumulations on the GUCP were typical.

Some patches of frost were observed on the LH2 tank acreage, particularly the +Y-Z and the +Y+Z quadrants. Surface temperatures ranged from 32 to 40 degrees Fahrenheit. There were no acreage TPS anomalies. Two small frost spots were observed on the aft dome manhole cover closeout.

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

A 8-inches in length and .25 inches wide stress relief crack was observed in the –Y vertical strut TPS with no offset. This condition has been observed on previous vehicles and found acceptable for flight per the NSTS-08303 criteria.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost accumulations were present on the aft and inboard sides. 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. Likewise, a typical amount of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier outboard side, forward, and aft surfaces. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch. No leaks were observed on the GUCP or the LO2 and LH2 Orbiter T-0 umbilicals.

3.3 T-3 HOURS TO LAUNCH

After completion of the Final Inspection on the pad, surveillance continued from the Launch Control Center. Twenty-two remote-controlled television cameras and two infrared radiometers were utilized to perform scans of the vehicle. An increase of frost formation on the acreage TPS was detected due to a small increase in relative humidity (78%). Based on SURFICE predictions, OTV observations and weather forecasts it was determined that a second Final Inspection Team walkdown was not going to be required at T-20 minutes. The following table shows ambient condition, SURFICE prediction and IR surface temperatures at 0615 a.m. during the T-9 minutes built-in-hold

Ambient conditions – 0615hrs	SURFICE Predictions	IR Surface Readings
45 Degrees F.	LO2 ogive 33.32 Degrees F	LO2 Tank 35 Degrees F
67.5% RH	LO2 barrel 26.69 Degrees F	
9.9 knots	LH2 upper 22.39 Degrees F	LH2 Tank 34 – 36 Degrees F
296.8 degrees	LH2 lower 31.92 Degrees F	

At T-0 the Ice/Debris Team observed no ice conditions beyond acceptable LCC limits. Protuberance icing previously assessed did not increase. At T-2:30, the GOX vent seals were deflated and the GOX vent hood lifted. Although frost covered some of the ET nose cone louvers - an expected condition - no ice was detected. When the heated purge was removed by retraction of the GOX vent hood, frost continued to form on the louvers until liftoff. At the time of launch, there were no ice accumulations in the "no ice zone".

STS-102 was launched at 067:11:42:09.014 UTC (6:42 a.m. local) on 08 March 2001.

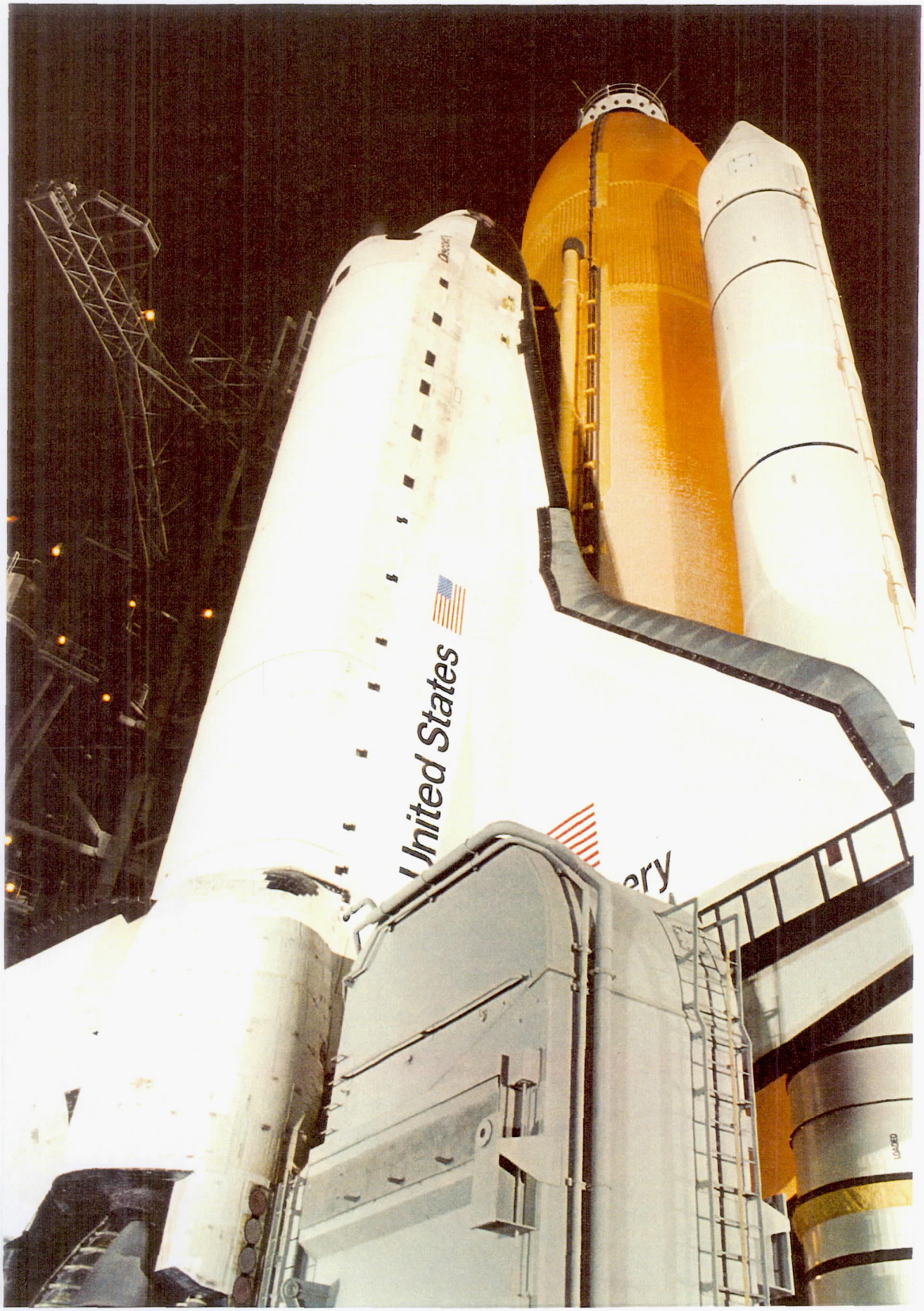


Photo 2: Frost on LH2 Tank

Some patches of frost had formed in the +Y+Z quadrant. Surface temperature ranged from 32 to 40 degrees Fahrenheit. Image taken during the FIT walkdown.

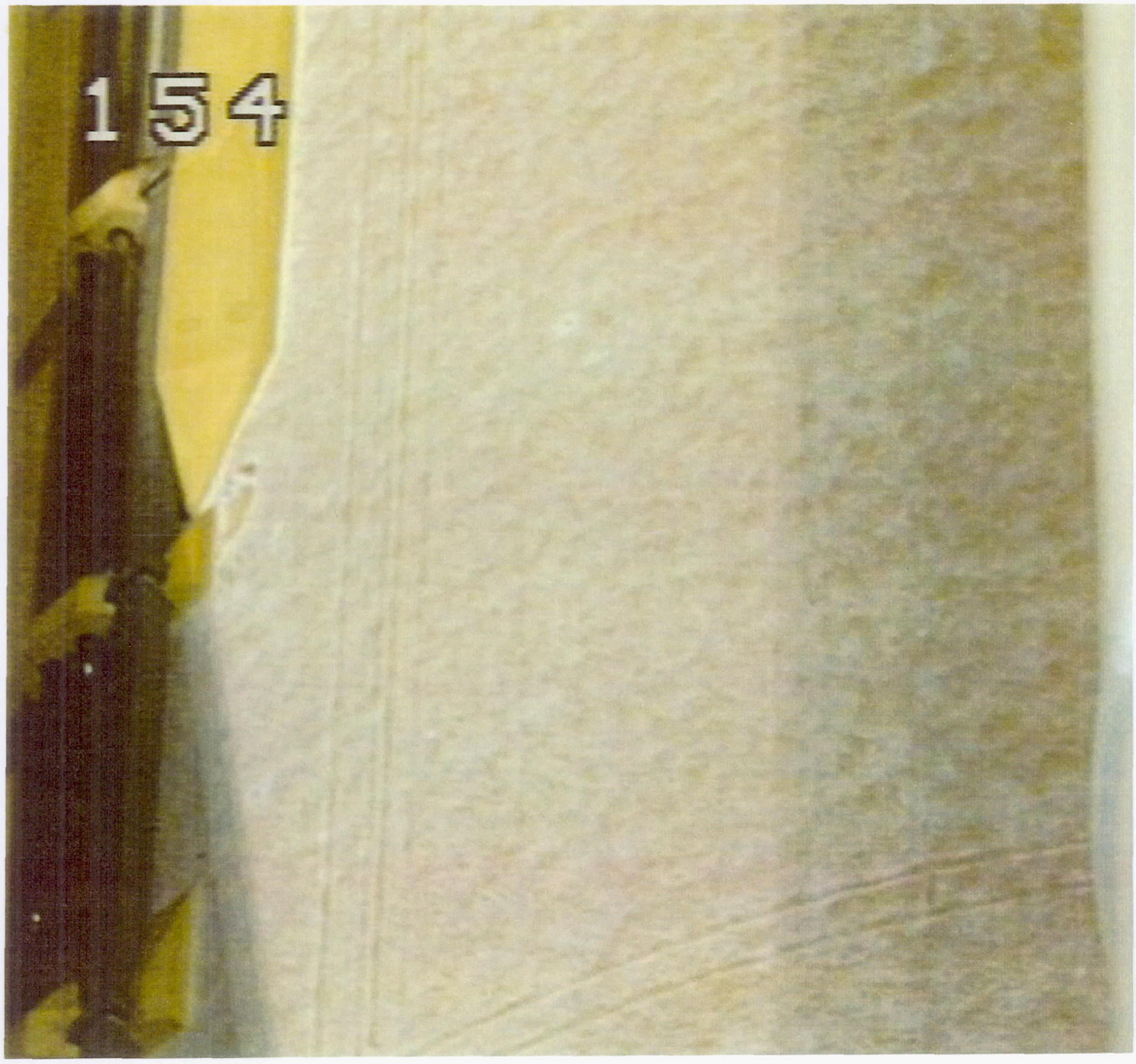


Photo 3: LH2 Tank Acreage

During OTV surveillance, after completion of the FIT walkdown, an increase in frost formation was observed on the LH2 tank acreage. This image was captured by OTV camera 154 during the T-20 minutes built-in-hold.

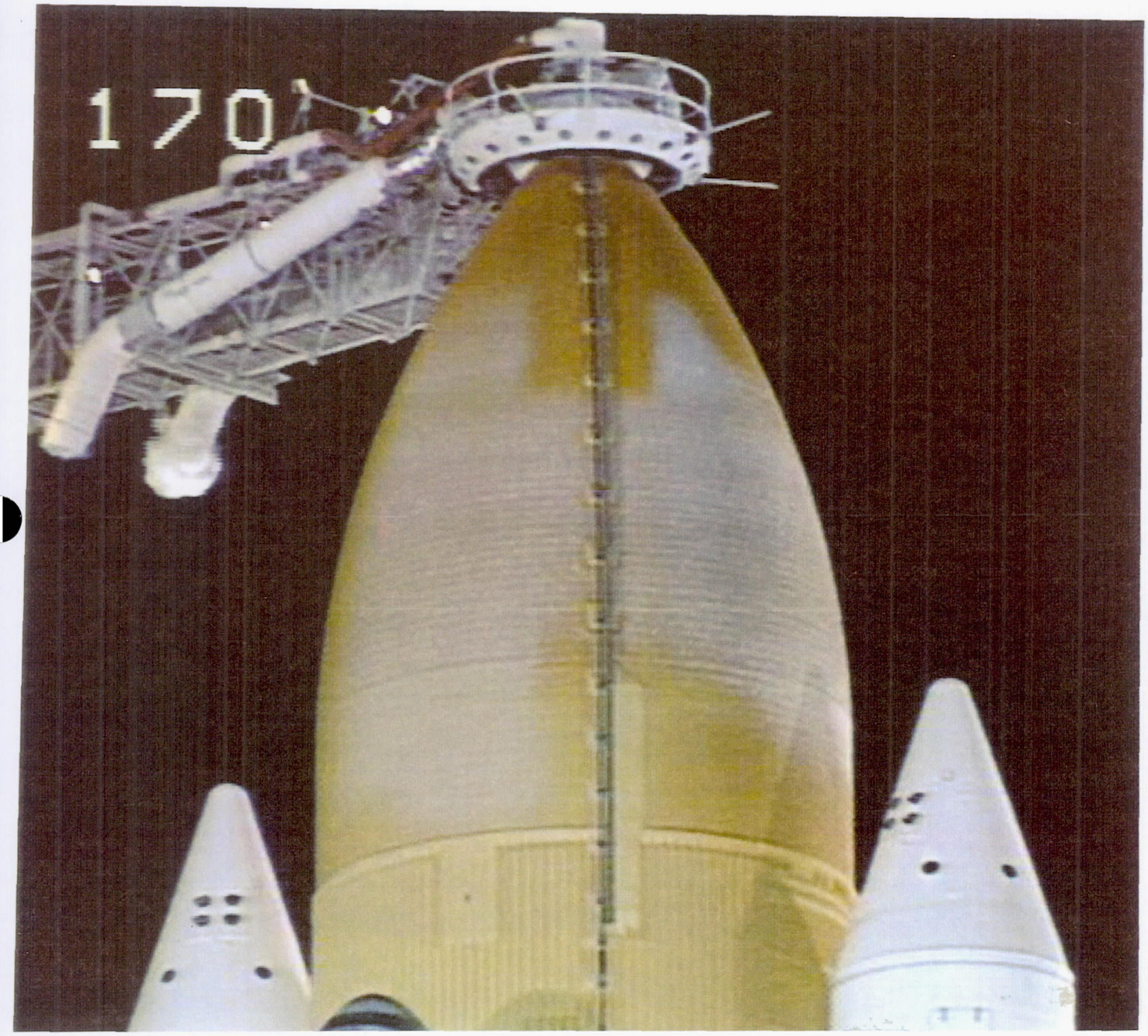


Photo 4: ET LO2 Tank Forward

Frost was present on the LO2 tank acreage. Surface temperature ranged from 32 to 41 degrees Fahrenheit. There were no acreage TPS anomalies. This image was captured by OTV camera 170 during the T-20 minutes built-in-hold.

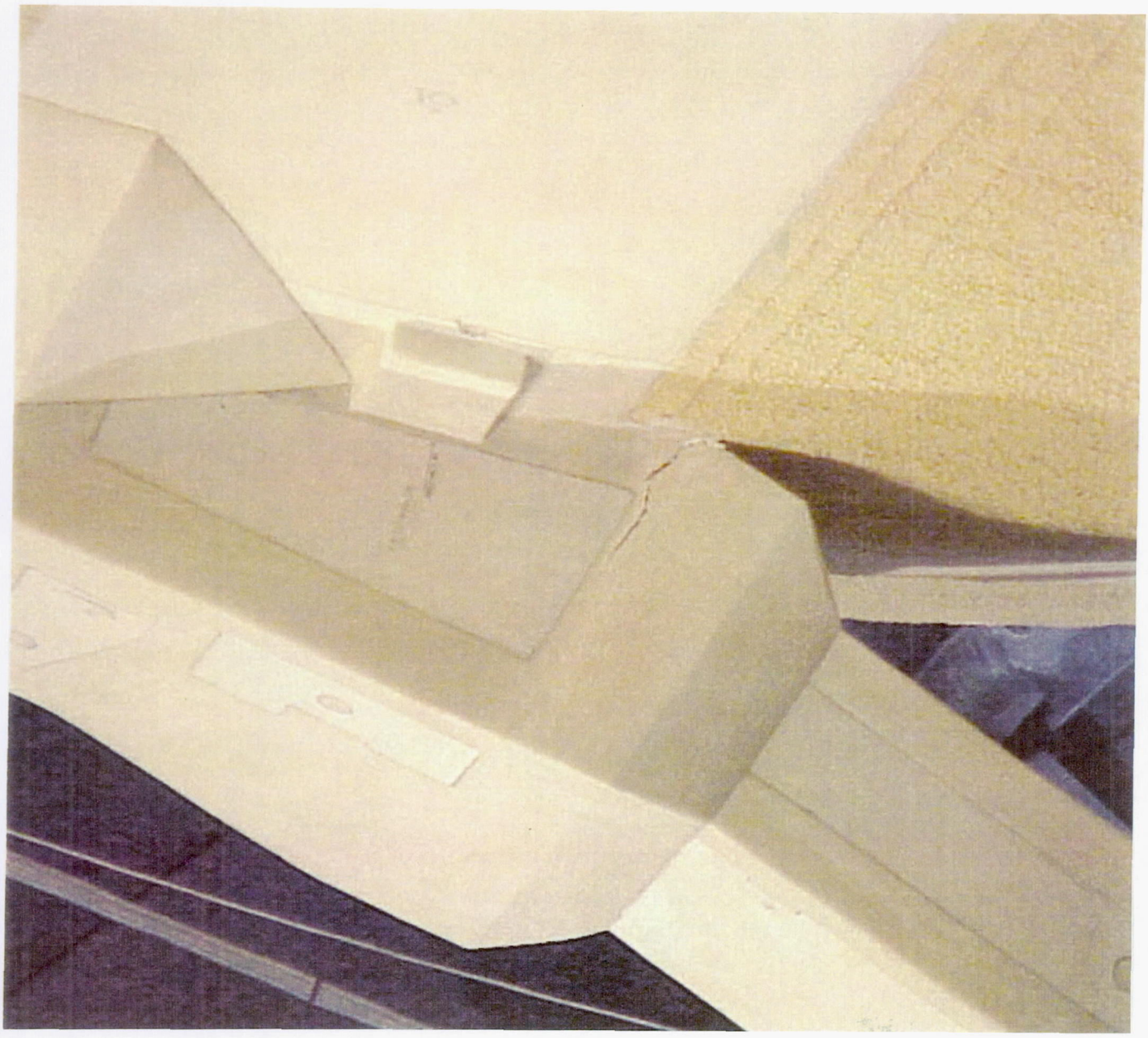


Photo 5: Cracks in –Y Vertical Strut

A 8-inches in length and .25 inches wide stress relief crack was observed in the –Y vertical strut TPS with no offset. This condition has been observed on previous vehicles and found acceptable for flight per the NSTS-08303 criteria.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP-3, Pad B FSS and RSS was conducted on 08 March 2001 from Launch + 2 to 4 hours (0815 to 1015 EST). No flight hardware was found.

Orbiter liftoff lateral acceleration data to predict stud hang-ups received from Boeing-Huntington Beach indicated that no SRB holddown stud hang-up had occurred. A HIM card failure prevented Debris team close-up evaluation of the holddown posts, as MLP 0-level was closed (Nitrogen flowing). Evaluation of the 0-level was performed from the FSS. Erosion was typical for the north posts. North holddown post blast covers and T-0 umbilical exhibited typical exhaust plume damage. Both SRB aft skirt GN2 purge lines were intact, protective tape layering was partially eroded.

The LO2 and LH2 Tail Service Masts (TSM) appeared undamaged and the LO2 bonnet was observed to have closed properly. The MLP deck was in generally good shape.

The GH2 vent line latched in the third of eight teeth of the latching mechanism. The GUCP 7-inch QD sealing surface exhibited no damage, the lip had a dent at the bottom-most location (6 o'clock position). The spool weldment strut had contacted the left-hand latch assembly. The latch was bent slightly. The left-hand side of the GH2 vent line arresting cable was noticeably frayed on the outer surface of the cable.

The OAA appeared to be intact with no evidence of plume impingement.

All slidewire baskets were secured with no evidence of damage.

The GOX vent arm, hood, ducts and structure appeared to be in good shape with no indications of plume damage.

Debris findings included:

- Three areas of damage (missing material) were noted on the north flame deflector.
- No flight debris was found on the Pad apron or adjacent grass.
- No unusual debris items were found on the FSS

Overall, damage to the pad appeared to be minimal. Minimal debris was noted on pad apron and FSS.

5.0 FILM REVIEW

No significant anomalies were observed during the review of the STS-102 Films/videos that would had been required to be elevated to the Mission Management Team, Shuttle managers, vehicle systems engineers, and to Program Integration.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 62 films and videos, which included twenty-seven 16mm films, sixteen 35mm films, and nineteen videos, were reviewed starting on launch day.

OTV cameras (168 and 169) mounted in the GOX Vent Hood clearly showed no ice or frost formation on the ET louvers during cryogenic loading and stable replenish. Frost, but no ice, formed when the purge was terminated and the hood lifted at T – 2:30.

SSME ignition appeared normal (OTV 151). SSME Mach diamond formation sequence was 2-3-1. Normally, the sequence is 3-2-1. A considerable amount of free burning hydrogen was visible in the orbiter base heat shield area and rising to the vertical stabilizer before dissipating. Several debris-induced streaks were observed in the SSME plume (E-54, E-220, E-222, E-223, E-224).

Body flap and elevon movement during ascent were typical (E-207, E-212, E-220).

Base heat shield movement during SSME ignition was typical (E-76, E-77).

A piece of SRB aft skirt instafoam material broke off during lift off due to contact with shoe retainer bracket on hold down post #4 (E-7) (11:42:09.438 UTC). Another piece of instafoam broke off due to contact with hold down post #7 shoe (E-11) (11:42:09.595 UTC).

Tile surface coating material was lost from several tiles on the Orbiter base heat shield outboard of SSME #2 and #3 as well as from the left hand RCS stinger. This is a common occurrence due to SSME ignition acoustics.

Numerous pieces of ice from the ET/ORB umbilicals shook loose and contacted umbilical sill tiles and ET cable tray TPS, but no damage was detected (OTV 109,163, E-77).

Acreage frost pattern was visible on the LOX and LH2 tanks. No change in the frost pattern had been observed from the OTV view during the final stages of the launch countdown (OTV 141, 160, 170, TV 4)

LH2 and LO2 T-0 umbilical disconnect was normal (OTV 149, 150).

GUCP disconnect from the ET was nominal (E-33).

Numerous pieces of SRB throat plug material ejected from the SRB exhaust hole; none were observed to contact the Orbiter lower surface. (E-54, E-77, E-222).

Particles of SRB aft-skirt instafoam fell along side the SRB plume (E-212). The amount and frequency of instafoam debris was less than what was observed during last mission.

Facility debris observed passing through field of view well after the vehicle had cleared the tower. Quantity and size appeared to be less than typical. (E-63, E-76, E-77)

SRB separation appeared normal. The effect of forward RCS firing on the BSM plume during SRB separation was not visible. (E-207, E-212)

NASA helicopter was observed west of the pad shortly after the vehicle cleared the tower. (E-52, E-54)

Charring on the ET aft dome was typical. (E-52, E-54, E-207, E-222, E-224)

Umbilical purge barrier baggy material fell shortly after T-0, and later after roll maneuver. (E-54)

Debris particles, possibly purge barrier baggy, instafoam, or ET hydrogen fire detection paper, observed trailing aft near ET LH2 aft dome – between 11:42:24.819 UTC and 11:42:28.914 UTC. (E-54)

Debris particles, probably forward RCS paper cover, were observed trailing aft in the vicinity of the left OMS pod just prior to SRB separation. (E-207)

Debris particle, forward of the –Y thrust strut, seen falling aft shortly after SRB ignition. The length of the debris particle appears to be no more than 11 inches in length and no more than two inches in width. (OTV 109).

The spray pattern from the LH2 TSM south ROFI became intermittent during SSME startup. Films E-3 and E-20 was reviewed by the pyro system personnel, per their expert evaluation the ROFI performance was found acceptable.

No stud hang up, or ordnance fragments, were observed on any of the SRB hold-down posts.

Multiple pieces of umbilical purge curtain (LH2 and LO2) were observed falling aft during SSME ignition, and during lift off. This is normally observed after the roll maneuver.

Ice particles fell aft crossing field of view past the right hand wing from the RHSRB EB-fitting. No contact with the Orbiter lower surface was noted.

Two distinct flashes accompanied with trailing puffs, occurred in the vicinity of OMS pods. They appeared to be associated with OMS assist burn, shortly after SRB separation. (E-205)

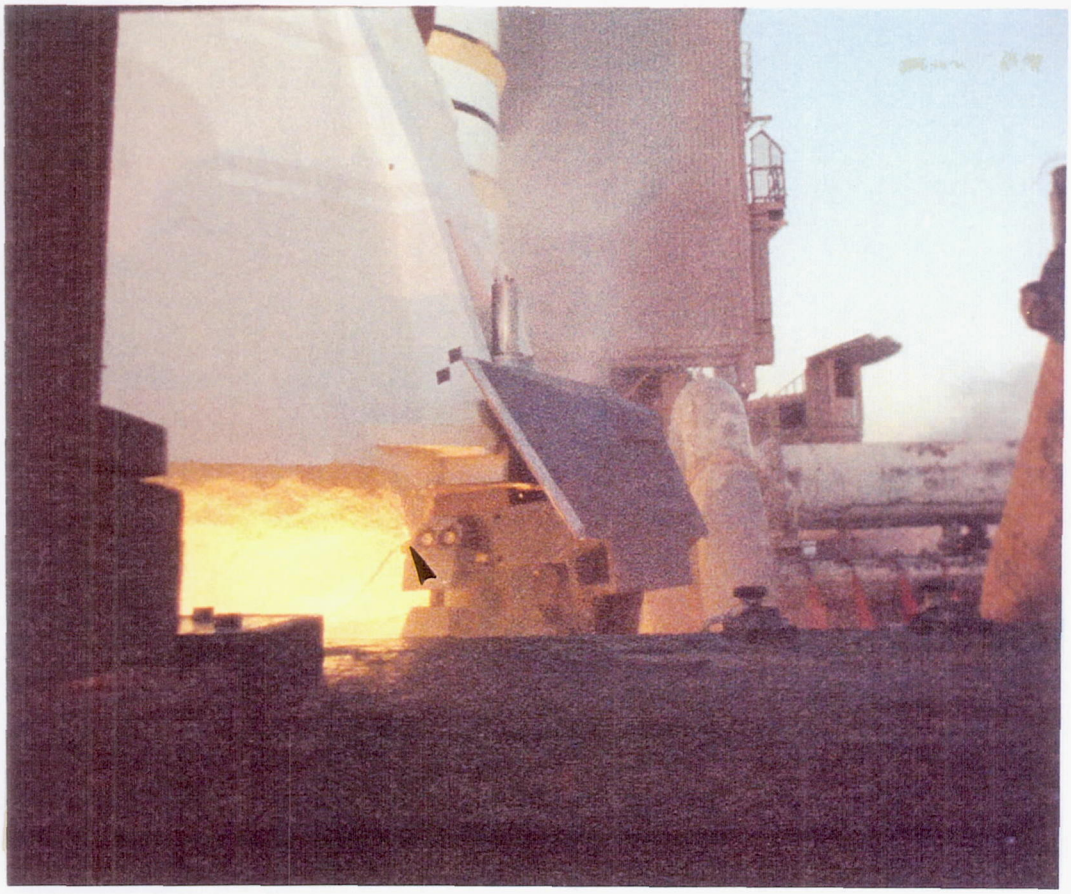


Photo 8: SRB aft skirt instafoam material broke off during lift off

Piece of SRB aft skirt instafoam material broke off during lift off due to contact with shoe retainer bracket on hold down post #4 (E-7) (11:42:09.438 UTC). Another piece of instafoam broke off due to contact with hold down post #7 shoe (E-11) (11:42:09.595 UTC)..

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

As expected, no Solid Rocket Booster separation photography was acquired on STS-102. The two 16 mm umbilical well high-speed motion film cameras were not flown on this mission.

The 35mm still images from the LO2 ET/ORB umbilical camera and Crew Hand-Held Still Images, of the External Tank after separation from the Orbiter were received and reviewed at KSC on 27 March 2001. All images were in clear focus. Although the lighting was excellent for areas to the +Y side of the LO2 feedline, the –Y side of the ET was in deep shadow.

No anomalies or significant missing TPS was detected and the ET appeared in excellent condition.

The visible portion of the +Y thrust panel exhibited no divots or anomalies

The red-colored purge seal that normally fits around the EO-3 ball fitting had come loose and floated aft by its tether.

The EO-3 (LO2 side) separation bolt protrusion was noted. Protrusion appeared to be less than EO-3 bolt protrusion observed on STS-106 film. Shuttle Program investigation determined no anomaly for STS-106 bolt extension.

No damage was detected on the LO2 ET/ORB umbilical disconnect, sealing surfaces, or closeout TPS. Typical ablation and divoting was noted on the vertical portion of the umbilical cable tray.

Some small, irregular, white or light-colored objects floating in field of view is believed to be pieces of frozen oxygen or hydrogen.

No anomalies were detected in the LO2 tank acreage. The BSM burn scars were typical.

Normal amounts of TPS erosion and topcoat charring occurred on the forward ogive near the nose cone, but no divots or grooves in the TPS were observed. The composite nose cone was in good condition.

Small amount of TPS erosion/ablation was observed on the forward face of the LH2 PAL ramp.

ET LH2 tank and intertank acreage appeared nominal.

The ablation/erosion of LO2 feedline flange closeouts was typical.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 17 films and videos, which included eight 35mm large format films and nine videos, were reviewed.

The landing gear extended properly. The right MLG tires contacted the runway first.
Drag chute deployment appeared normal. No anomalies were detected from touchdown through rollout. No unusual tile damage was visible in the films.

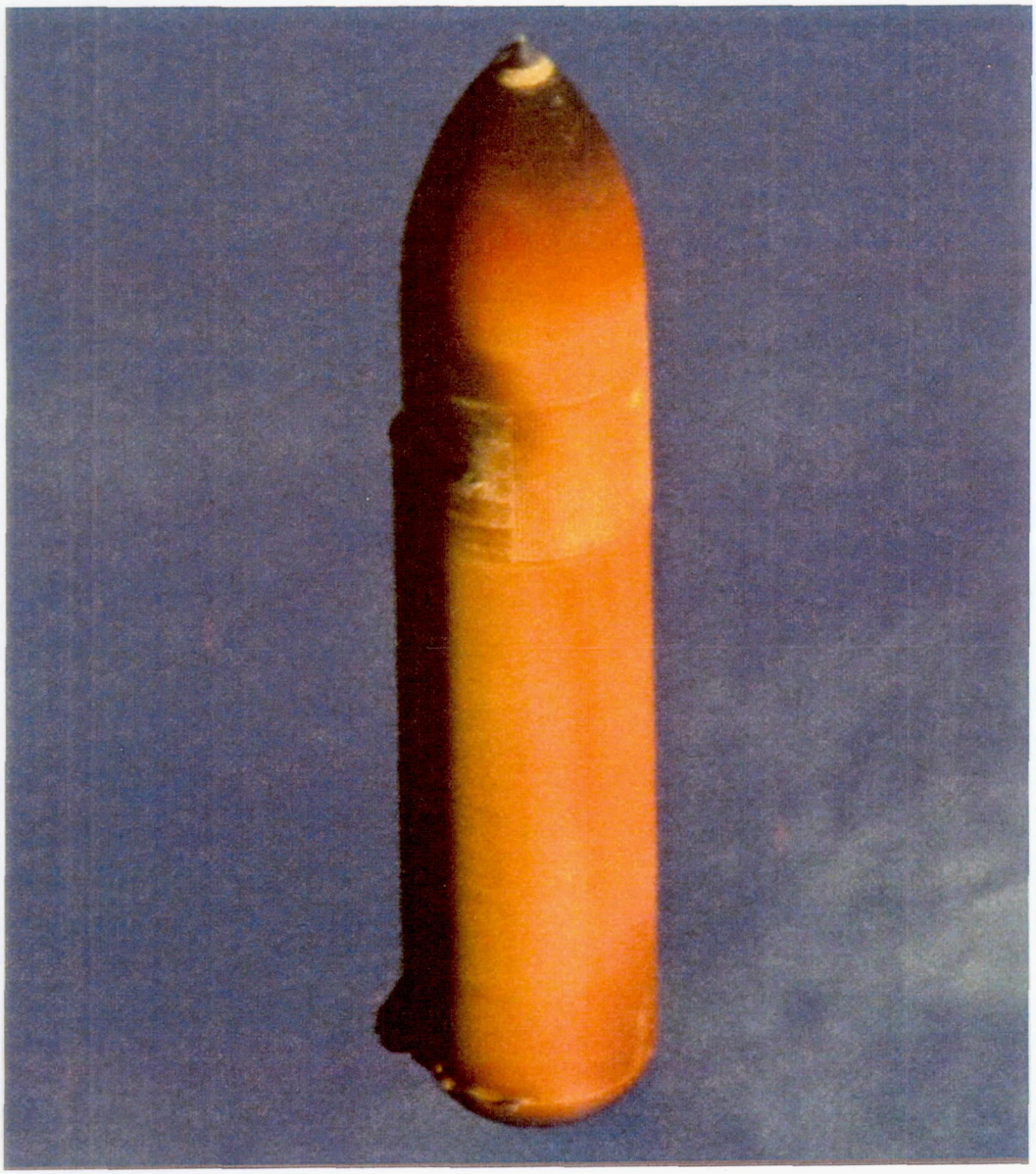


Photo 11: Astronaut Handheld Camera View of the External Tank

No anomalous condition were noticed

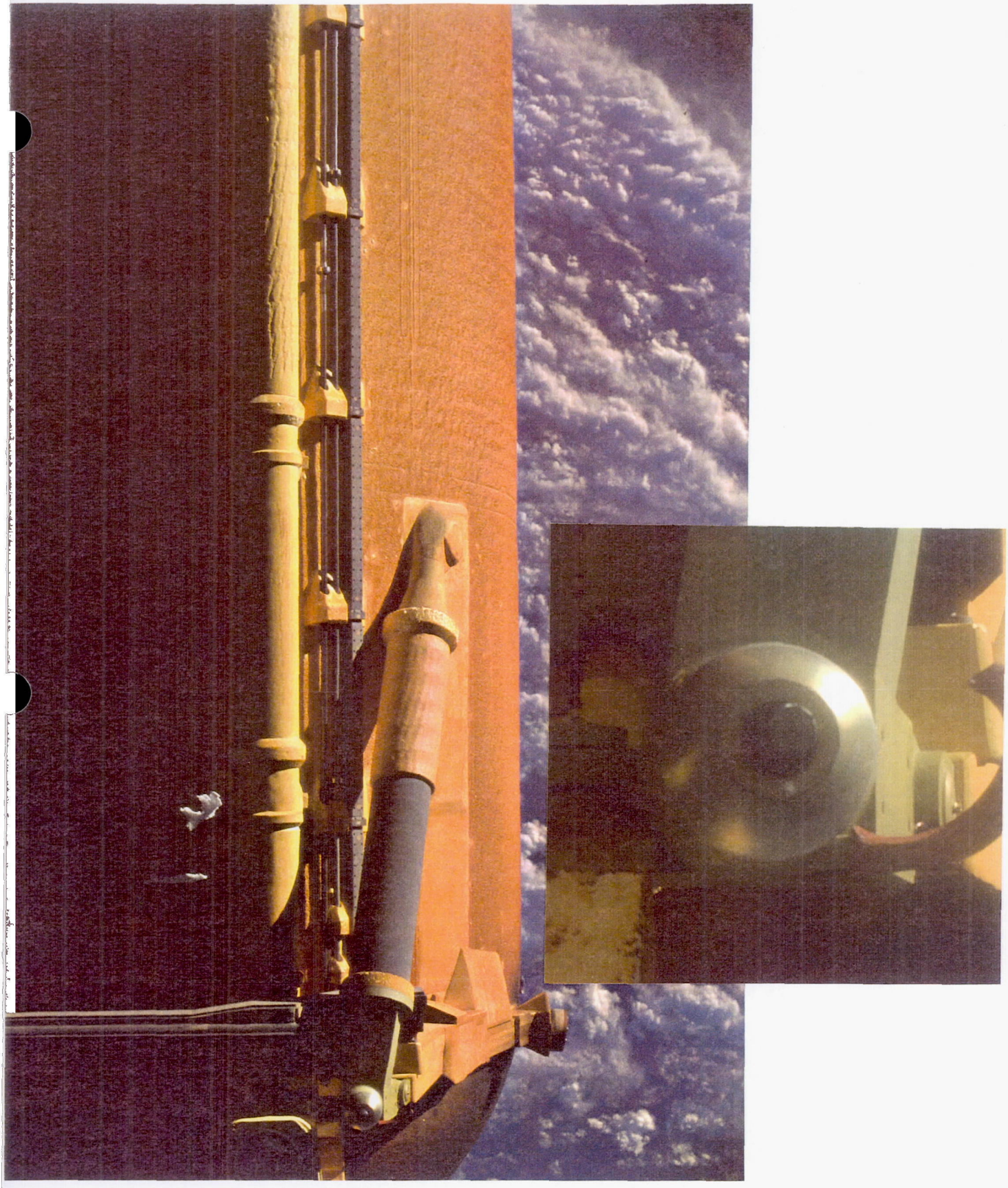


Photo 12: View of the External Tank after sep

No anomalous condition was noticed. EO-3 (LO2 side) separation bolt protrusion was observed.

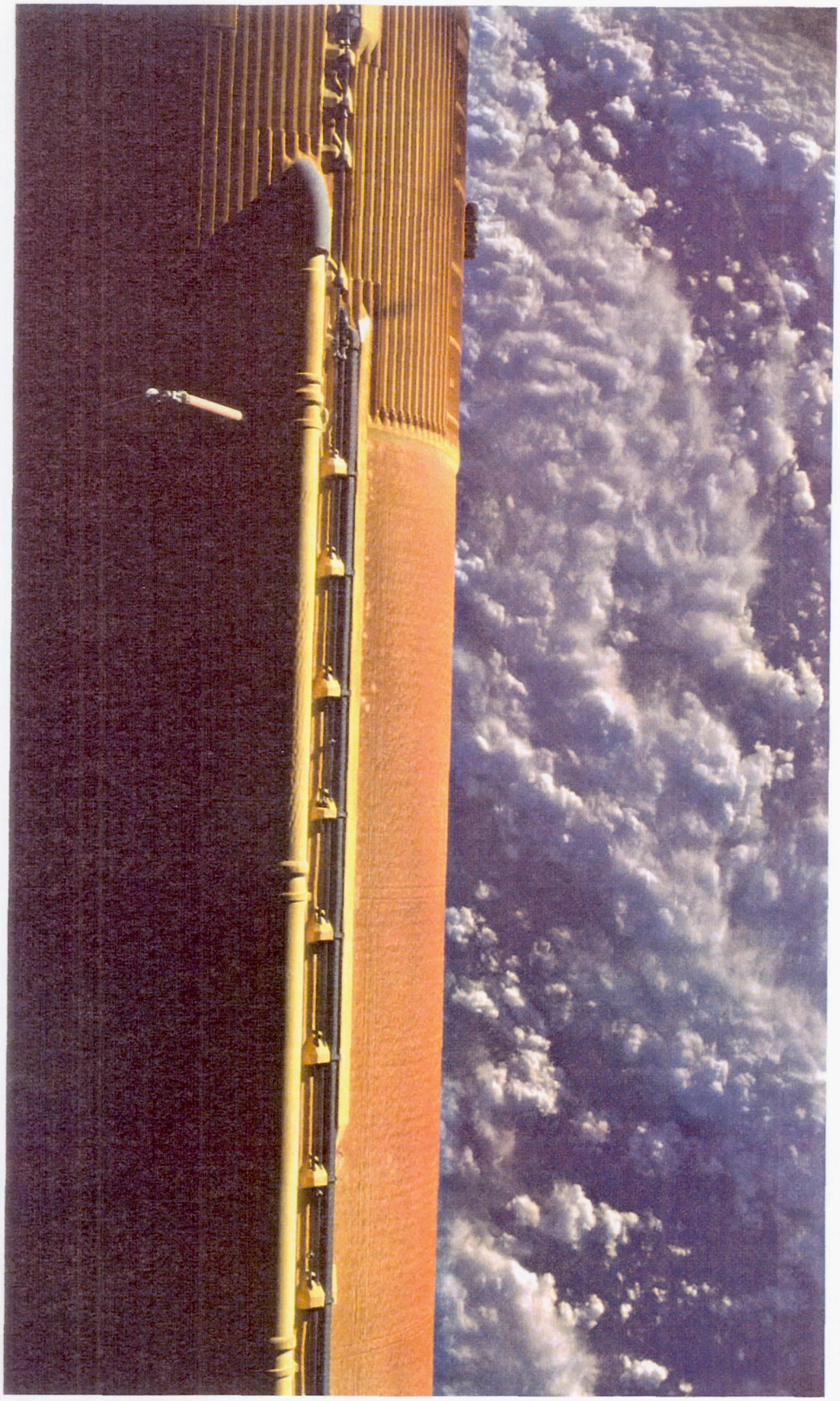


Photo 13: View of the External Tank after sep

No anomalous condition was noticed.

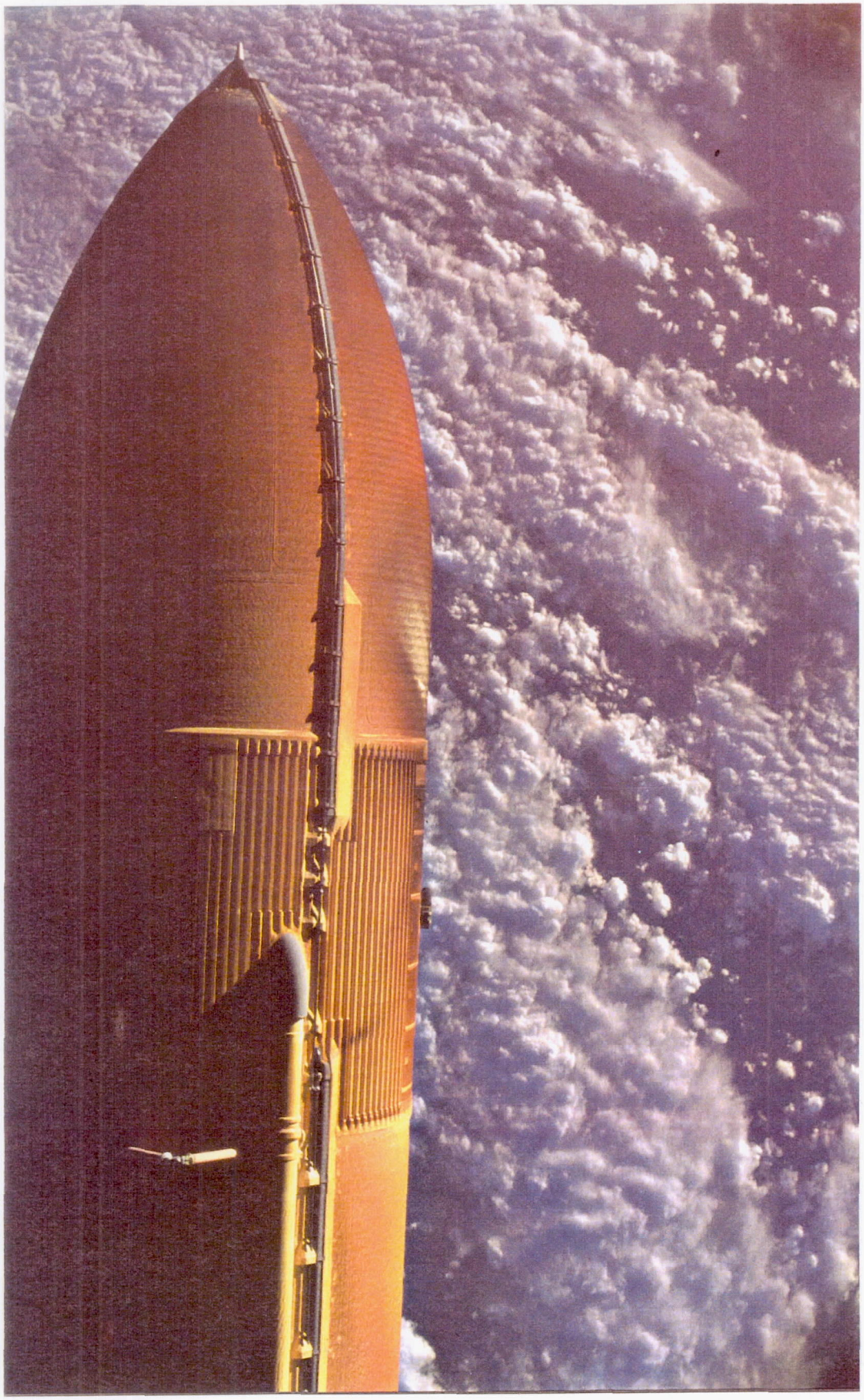


Photo 14: View of the External Tank after sep

No anomalous condition was noticed

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-106 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 12 March 2001. Generally, both boosters were in excellent condition.

The TPS on both frustums exhibited no debonds/unbonds.

All eight BSM aero heat shield covers had fully opened and locked, but two RH covers attach rings had been bent at the hinge by parachute riser entanglement.

The forward skirts exhibited no debonds or missing TPS. The RSS antennaes were intact. One pin retainer clip was bent up 90 degrees, but still installed in place.

The Field Joint Protection System (FJPS) and the System Tunnel Covers closeouts were generally in good condition with no unbonds observed.

Separation of the aft ET/SRB struts appeared normal.

Aft skirt external surface TPS was in good condition. Typical blistering of Hypalon paint had occurred on the BTA insulation close-outs and GEI cork runs.

The holddown post Debris Containment Systems (DCS) appeared to have functioned normally. No indication of stud hang up was observed.

In summary both SRB's were found in good condition regarding debris assessment.

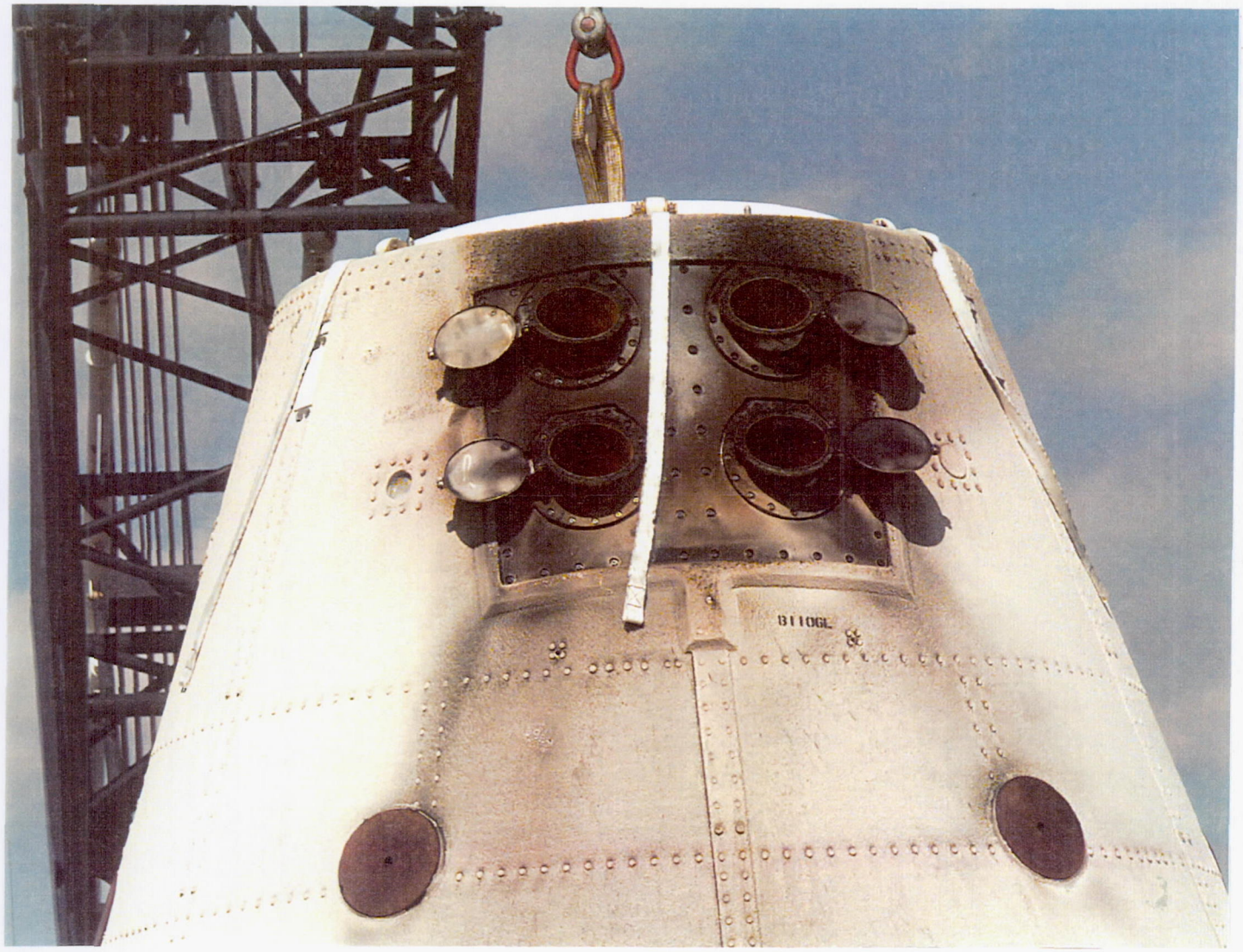


Photo 12: Frustum Post Flight Condition

The frustums exhibited no debonds/unbonds or missing TPS.
All eight BSM aero heat shield covers had locked in the typical opened position.

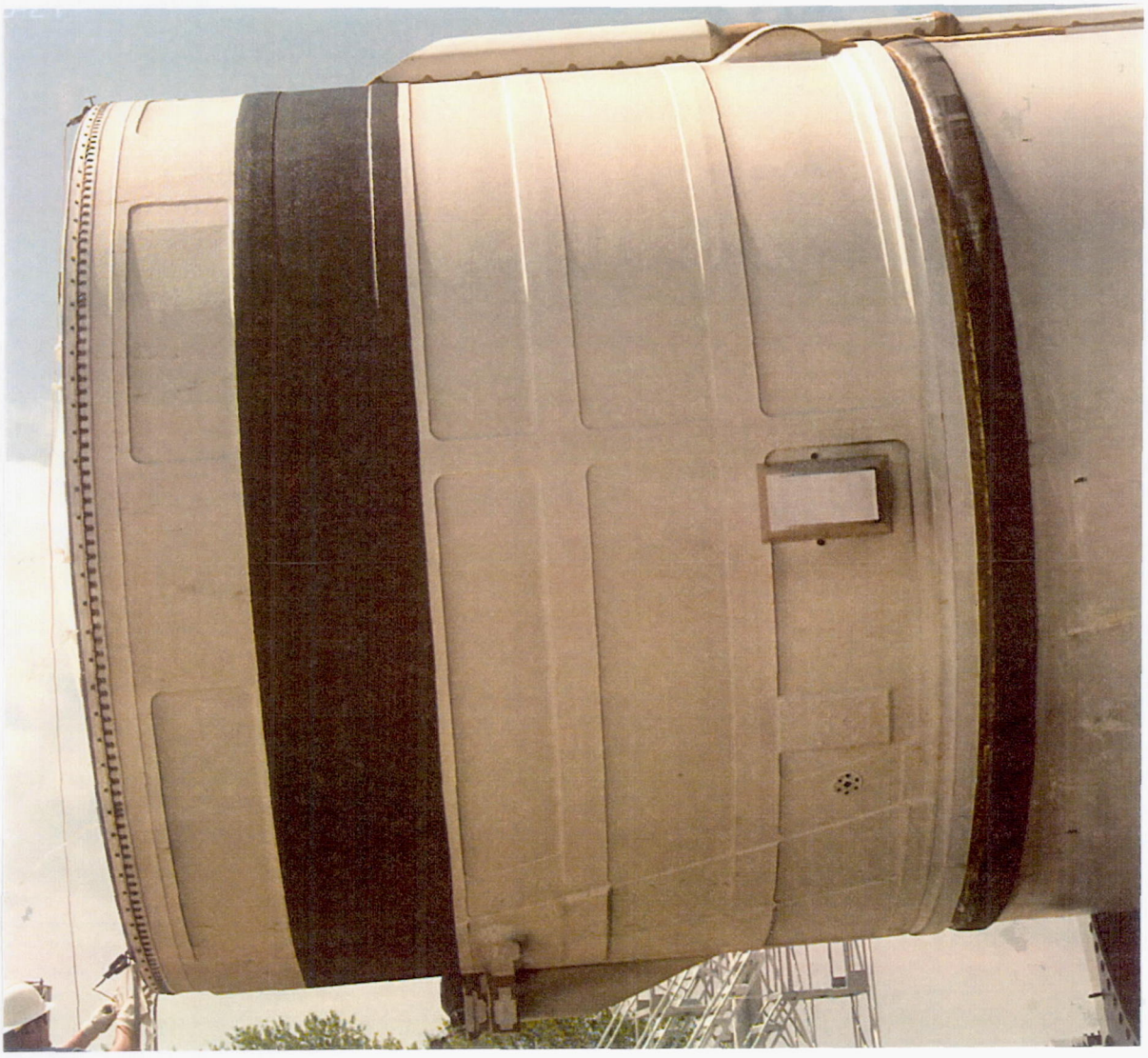


Photo 13: Forward Skirt Post Flight Condition

The forward skirts exhibited no debonds or missing TPS.

Photo 14: SRB Post Flight Condition

Both SRB's were found in good condition regarding debris assessment

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

After the 2:31 a.m. local/eastern time landing on 21 March 2001, a post landing inspection of OV-103 Discovery was conducted at the Kennedy Space Center on SLF runway 15 and in 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 100 hits of which 15 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shields attributed to SSME vibration/acoustics and exhaust plume recirculation.

The following table lists the STS-102 Orbiter damage hits by area:

	HITS > 1-inch	TOTAL HITS
Lower Surface	10	44
Upper Surface	0	0
Window Area	4	44
Right Side	0	4
Left Side	1	3
Right OMS Pod	0	1
Left OMS Pod	0	4
TOTALS	15	100

The Orbiter lower surface sustained 44 total hits, of which 10 had a major dimension of 1-inch or larger, both numbers are well within family. Approximately 14 damage sites (with two larger than 1-inch in length) were located in the area from the nose landing gear to the main landing gear wheel wells. The majority of the hits were around the LH2 umbilical area (22 hits). Most of these damage sites around the ET/ORB umbilical were most likely caused by pieces of the umbilical purge barrier flailing in the airstream and contacting tiles before pulling loose and falling aft. The ET TPS venting modifications continue to have a reducing effect on the quantity and size of the damage sites.

The largest lower surface tile damage site, located inboard of the LH2 umbilical, measured 1-inches long by 2-inches wide by 0.125-inches deep. A combination of umbilical ice and/or umbilical purge barrier material could have been the cause of this damage site.

Left hand RCC panel # 10 has a large damage at the leading edge, below apex curve, adjacent to the T-Seal. The damage was 2.0 inches long by .120 inches wide by .100 inches deep. Carbon substrate was exposed. The same panel also had what appeared to be a surface degradation in the middle lower region of panel that is approximately .5-inch diameter. Further investigation determined that the panel 10L damage was caused by subsurface oxidation across the coating-substrate interface and not by a debris impact.

The landing gear tires were reported to be in good condition. There was no ply under cutting on the main landing gear tires.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilicals. The EO-2 and EO-3 fitting retainer springs appeared to be in nominal configuration, though one of the "salad bowl" clips were missing from EO-3. The EO-2/3 pyro debris shutters were fully closed. A small piece of umbilical closeout foam (pyro can closeout) was adhered to the umbilical plate near the LO2 disconnect. No debris was found beneath the umbilicals.

Less than usual amounts of tile damage occurred on the base heat shield. Engine number 1 dome heat shield blanket has minor damage at 6 o'clock position.

No unusual tile damage occurred on the leading edges of the OMS pods. Only four small hits were noted on the leading edge of the left OMS pod and one small hit on the leading edge of the right OMS pod. One protruding tile gap filler material was found on the R/H OMS pod, approximately 2 inches long.

Four vertical tail leading edge tile damage sites were observed. One hit on the trailing edge of the Rudder/Speed Brake measured 1.75 inches long, 1.25 inches wide, and 0.25 inches deep.

Damage sites on the window perimeter tiles were more than usual in quantity. There were a total of 40 hits on the window perimeter tiles with four having dimensions greater than one inch. Hazing and streaking of forward-facing Orbiter windows was moderate.

The post-landing walkdown of Runway 15 was performed immediately after landing. All components (except a small white seal ring) of the drag chute were recovered and appeared to have functioned normally. A piece of AMES gap filler, 10 inches long by 1 inch wide, was found on the runway, tiles gap filler have been found on previous missions and is not considered an anomaly. Numerous pieces of facility paint chips were found right of centerline of runway 15. Largest pieces were approximately 3 inches x 2 inches.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were well within established family (reference Figures 3, 4 and 5).

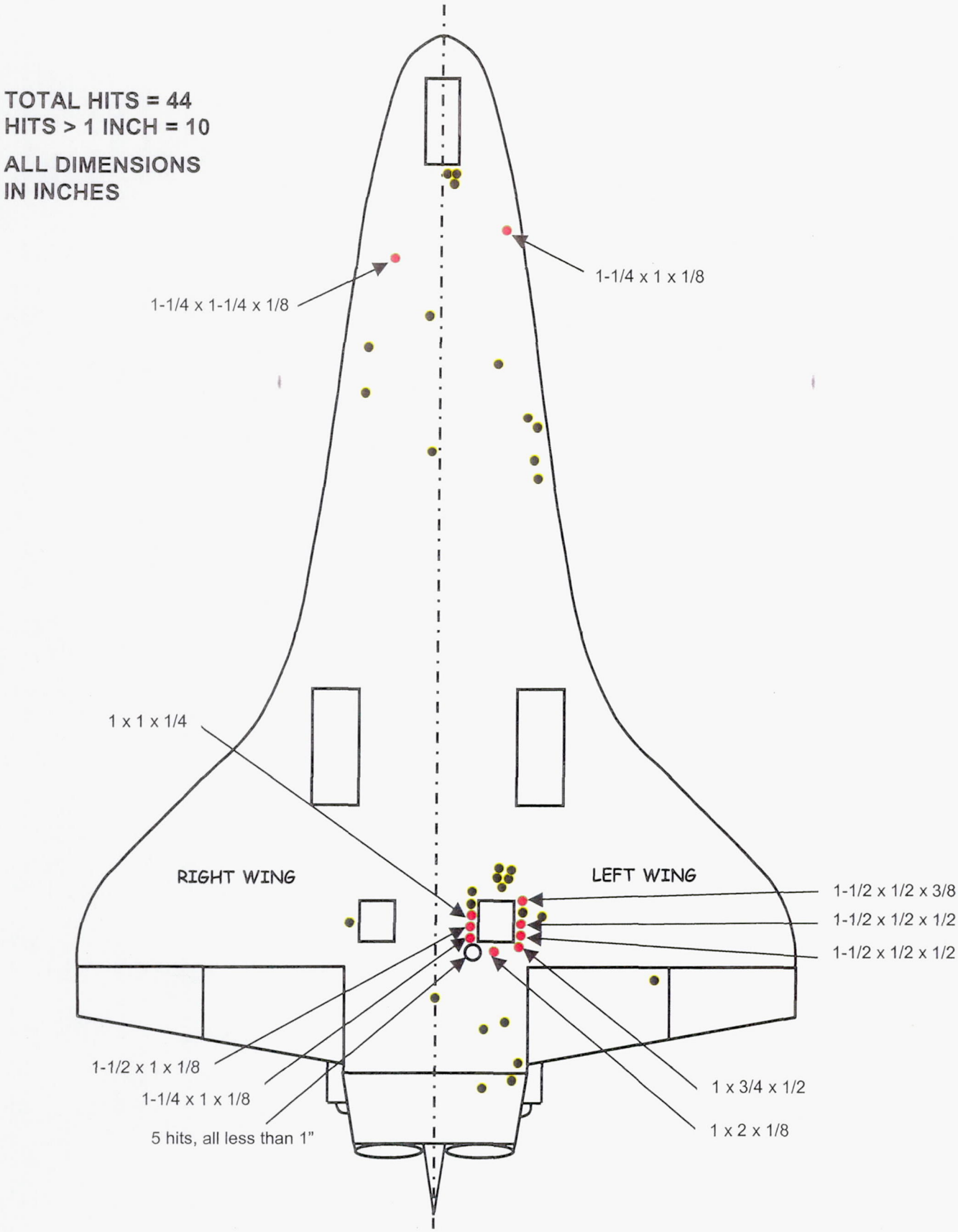


Figure 1: Orbiter Lower Surface Debris Damage Map

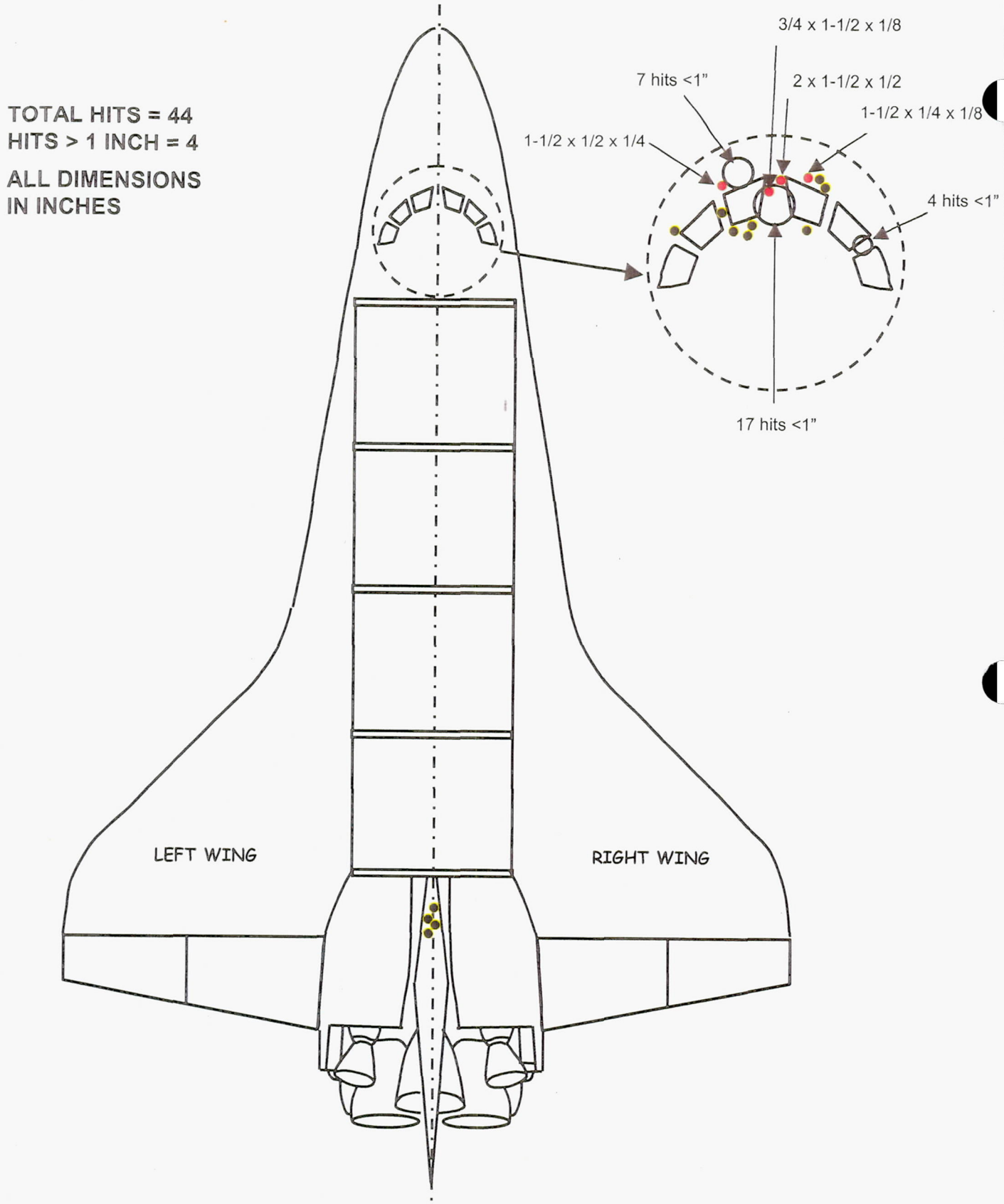


Figure 2: Orbiter Upper Surface Debris Damage Map

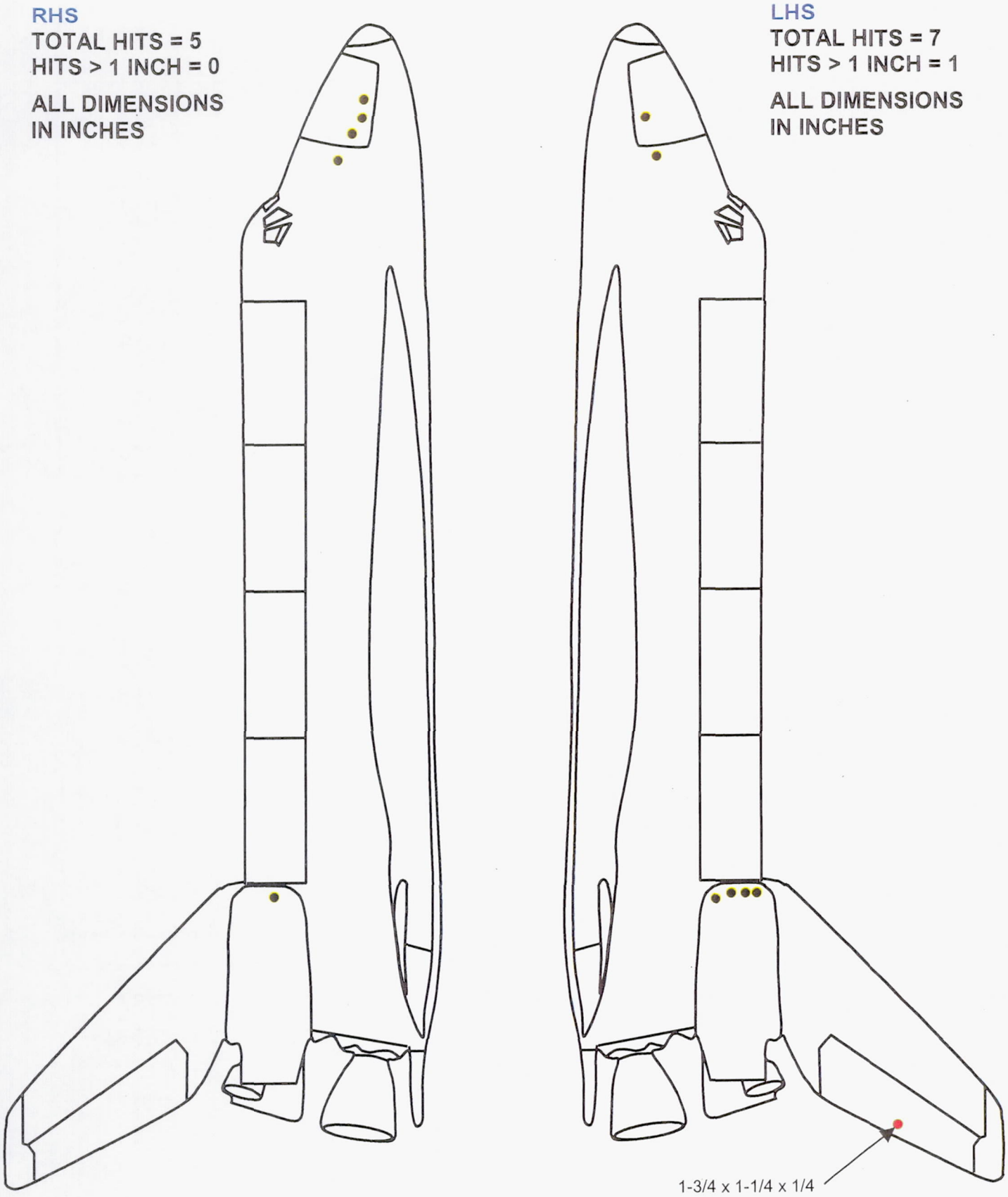
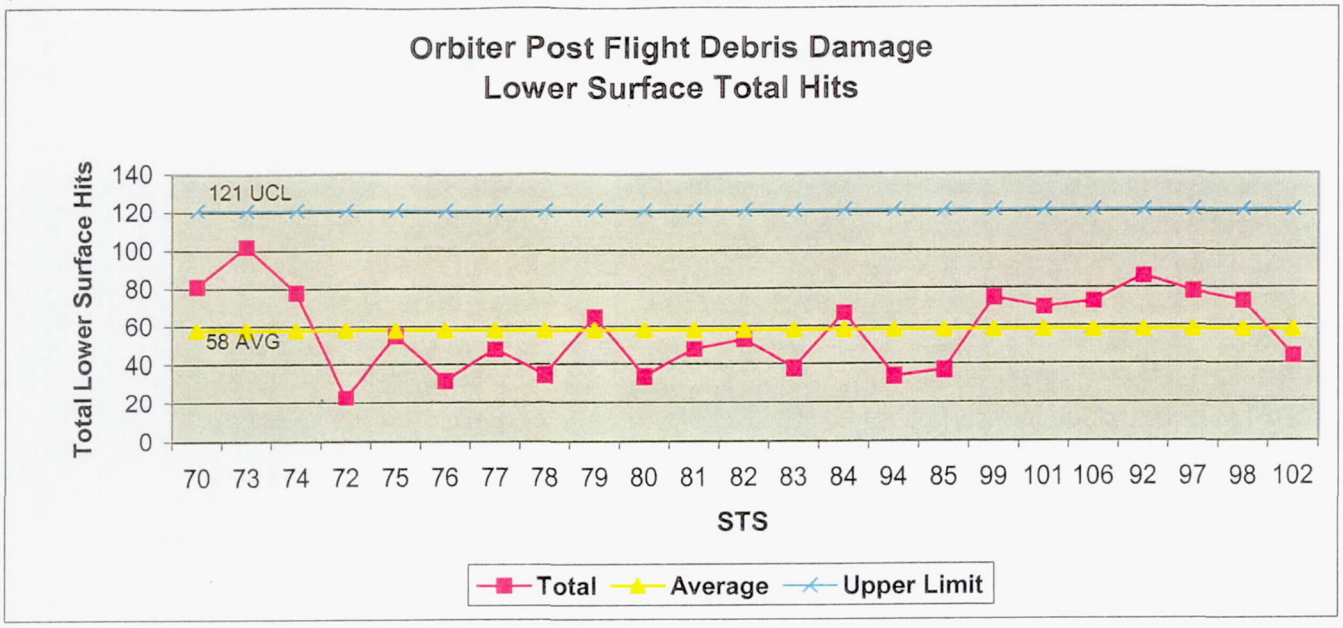


Figure 3: Orbiter Right/Left Sides Debris Damage Map

STS NUMBER	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
STS-75	11	55	17	96
STS-76	5	32	15	69
STS-77	15	48	17	81
STS-78	5	35	12	85
STS-79	8	65	11	103
STS-80	4	34	8	93
STS-81	14	48	15	100
STS-82	14	53	18	103
STS-83	7	38	13	81
STS-84	10	67	13	103
STS-94	11	34	12	90
STS-85	6	37	13	102
STS-99	21	75	25	88
STS-101	19	70	27	113
STS-106	17	73	17	105
STS-92	14	86	24	127
STS-97	10	78	10	84
STS-98	8	73	13	102
AVERAGE	11.4	63.5	16.0	103.0
SIGMA	5.7	32.1	6.3	28.6
STS-102	10	44	15	100

MISSIONS STS-86,87,89,90,91,95,88,96,93,103 ARE NOT INCLUDED SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 4: Orbiter Post Flight Debris Damage Summary



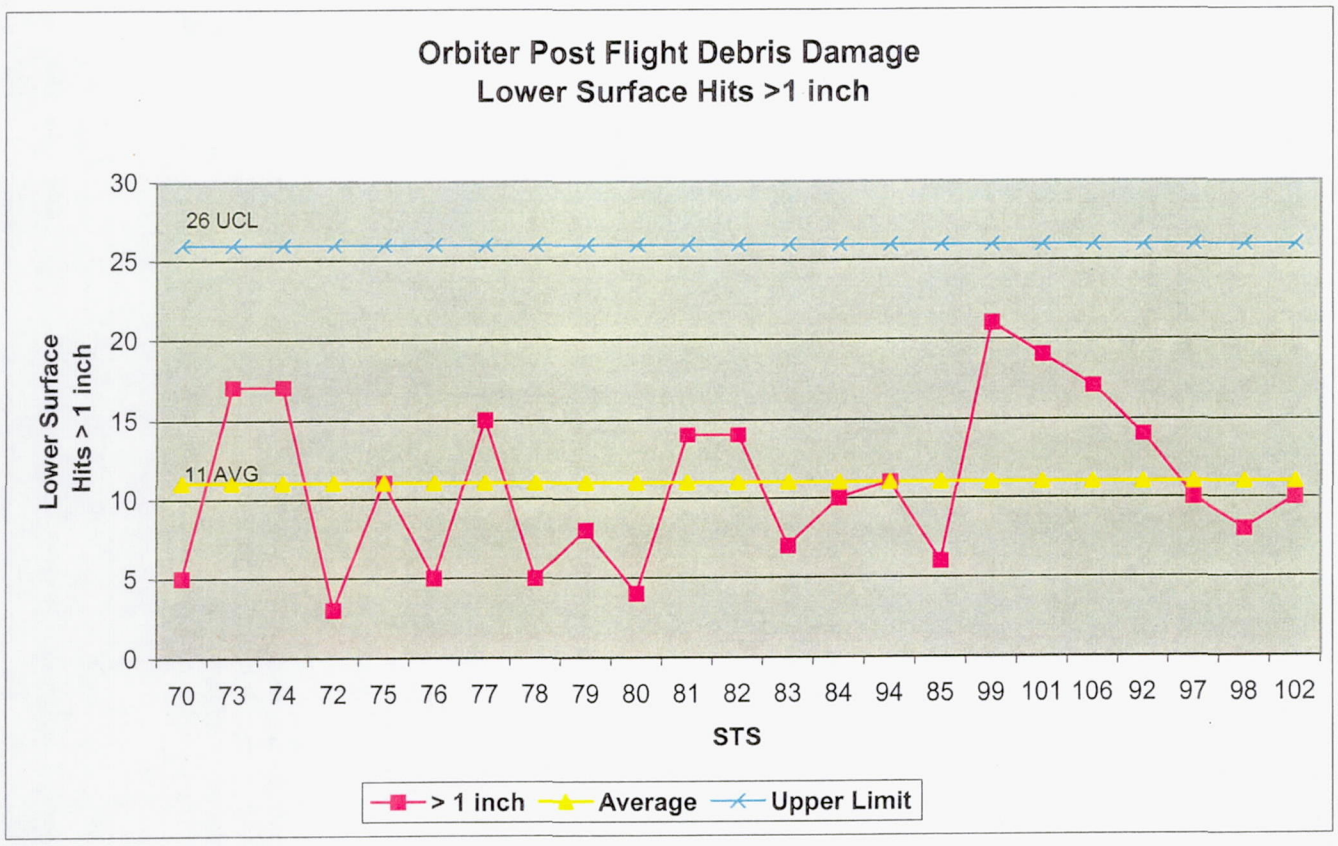
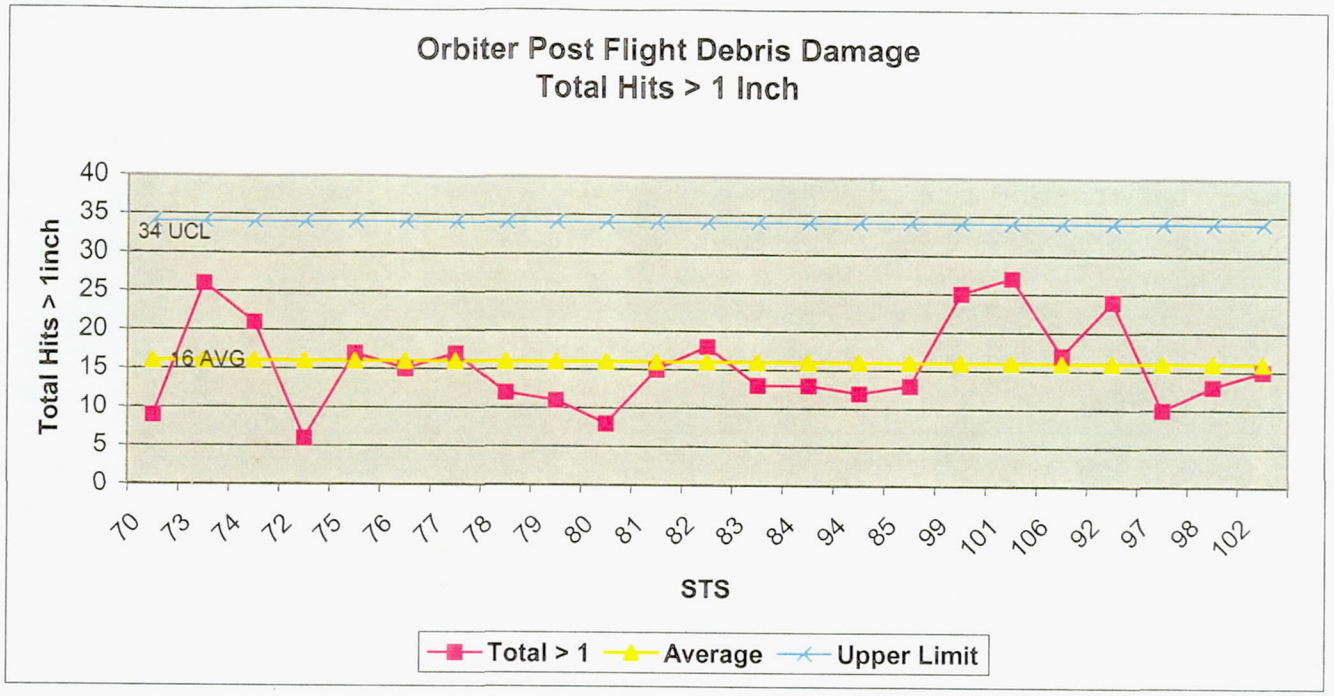


Figure 5: Control Limits for Lower Surface Hits



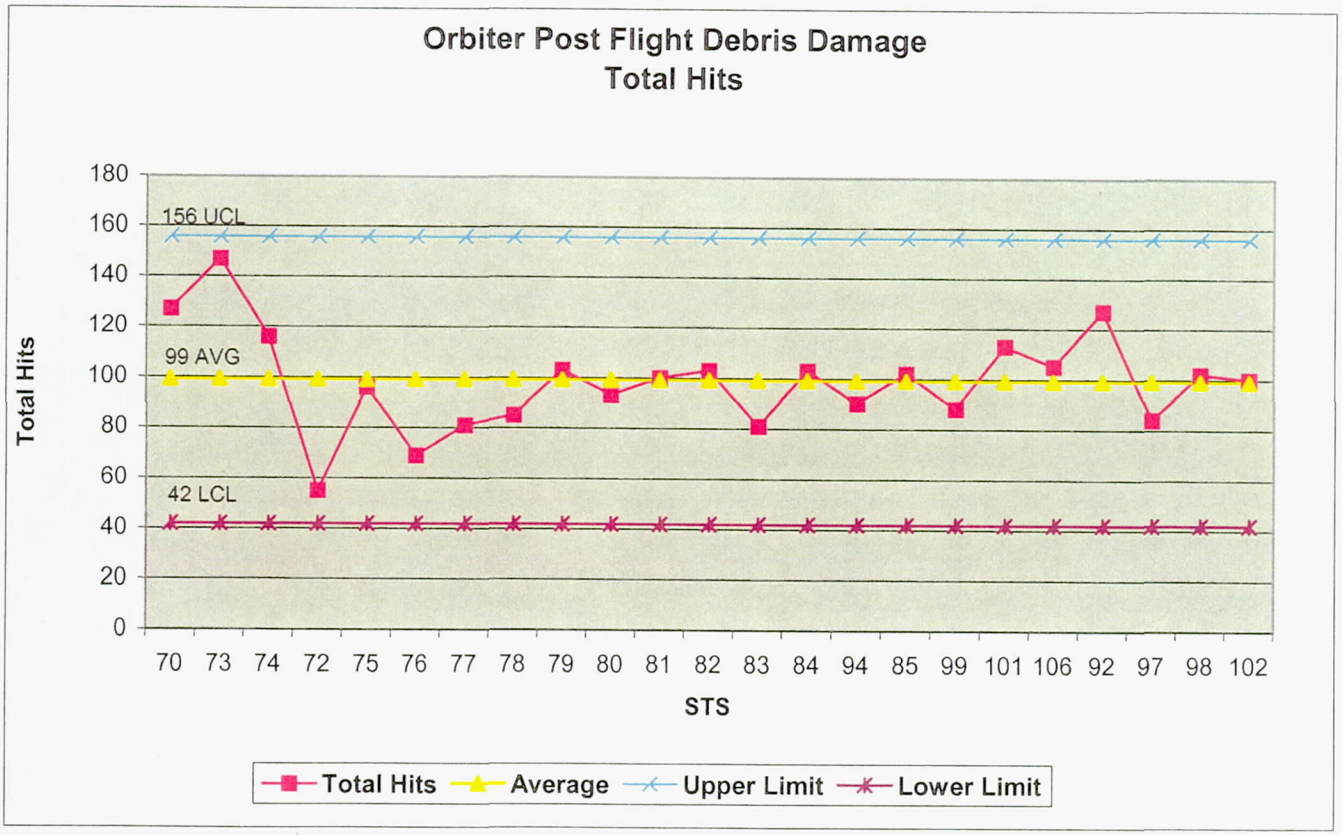


Figure 6: Control Limits for Total Hits

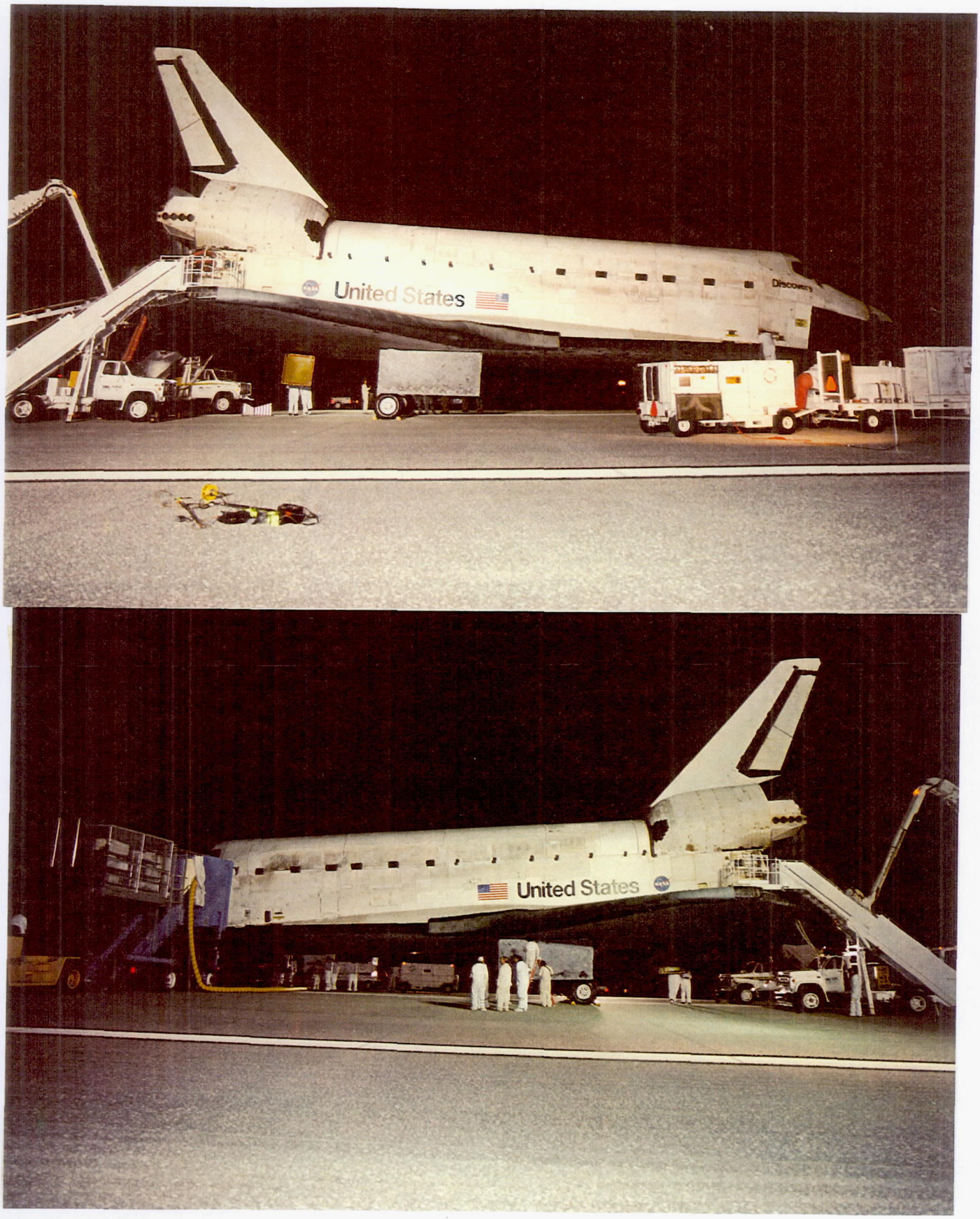


Photo 16: Overall View of Orbiter Sides

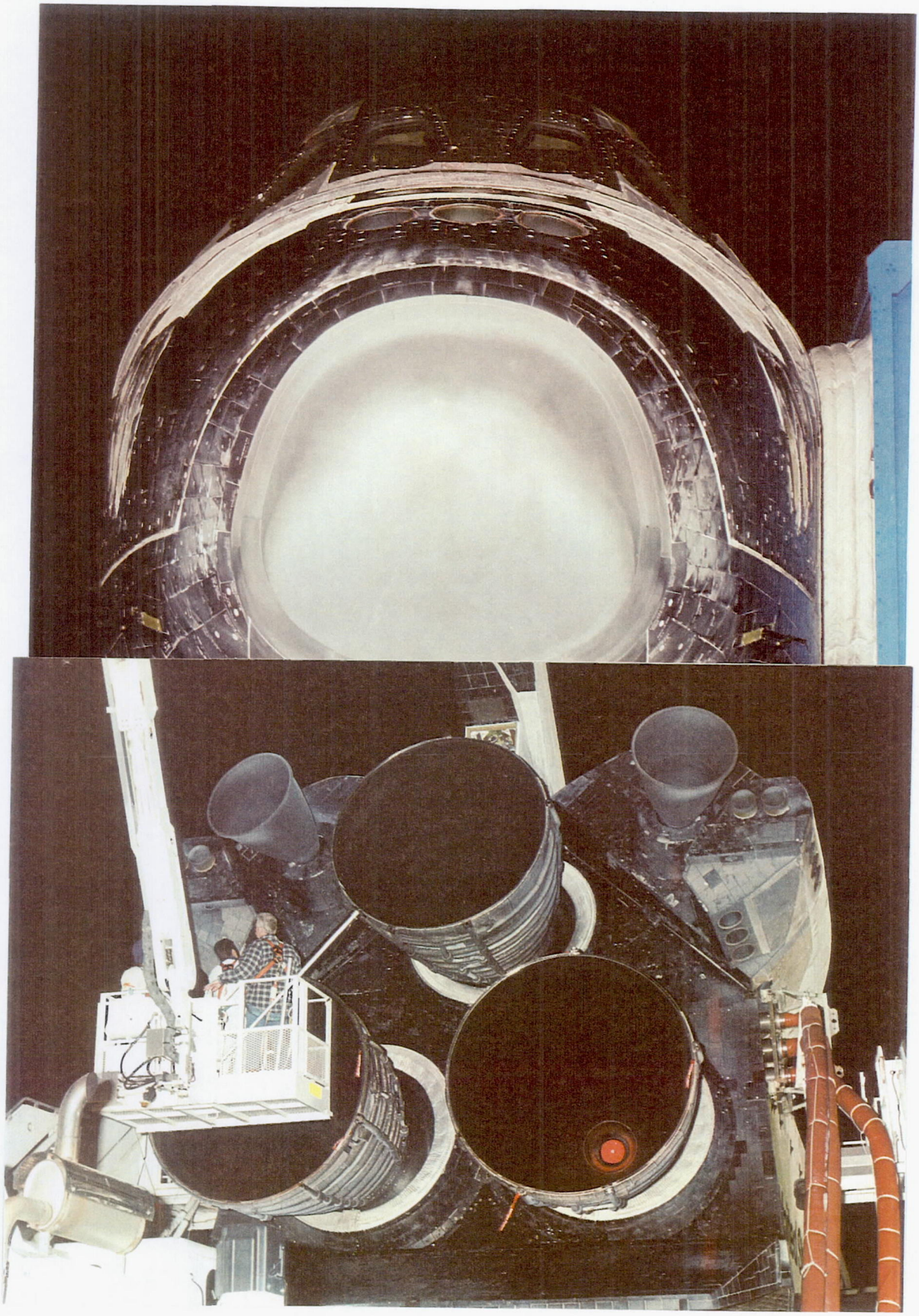


Photo 17: Windows and Base Heat Shield

Damage sites on the window perimeter tiles were more than usual in quantity. Less than usual amounts of tile damage occurred on the base heat shield. All SSME Dome Heat Shield closeout blankets were in excellent condition.

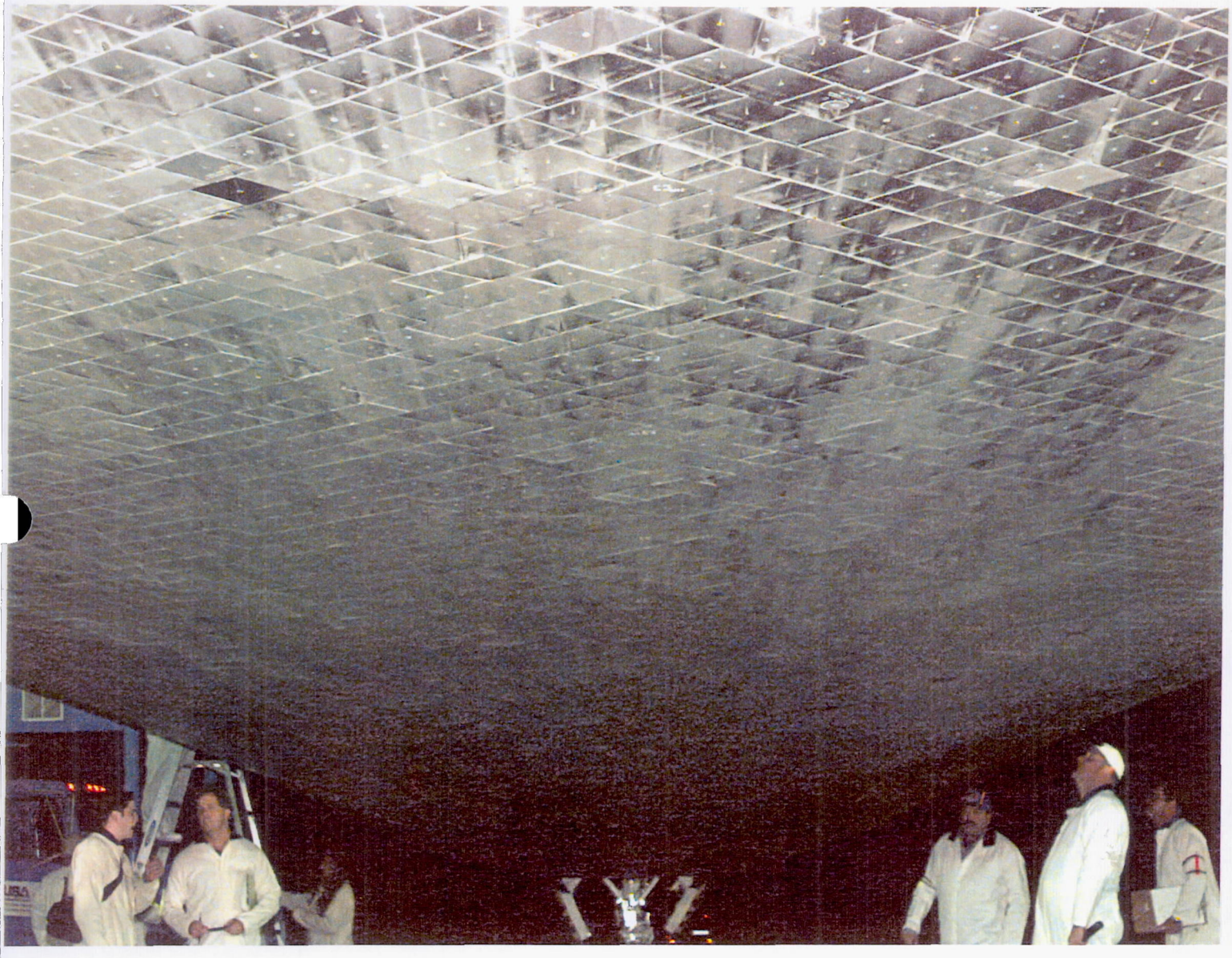


Photo 18: Damage to Lower Surface Tiles

The orbiter lower surface sustained only 44 total hits. Both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were well within established family

Photo 19: R/H OMS pod

One protruding tile gap filler material was found on the R/H OMS pod, approximately 2 inches long.

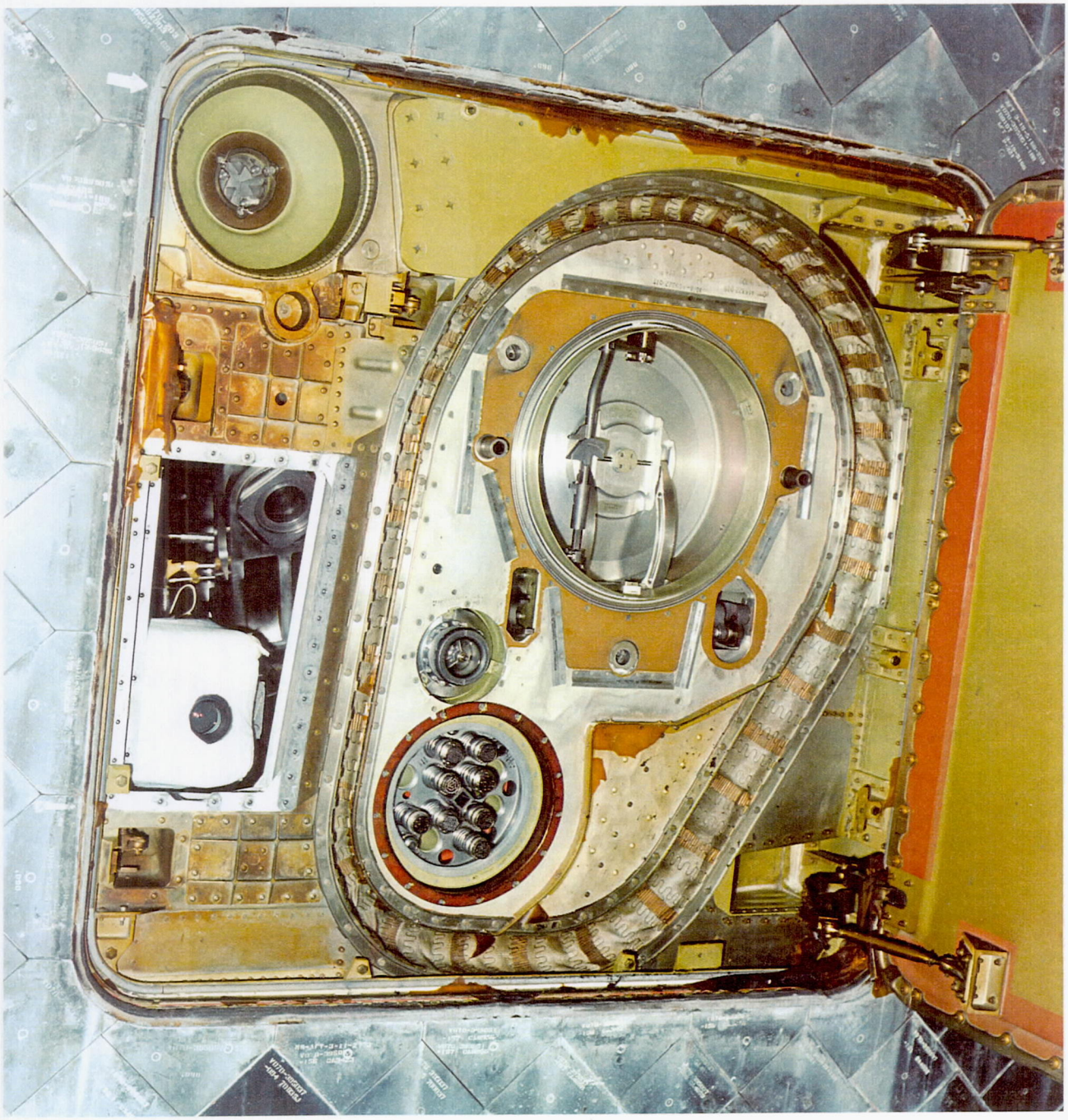


Photo 20: LO2 ET/ORB Umbilical

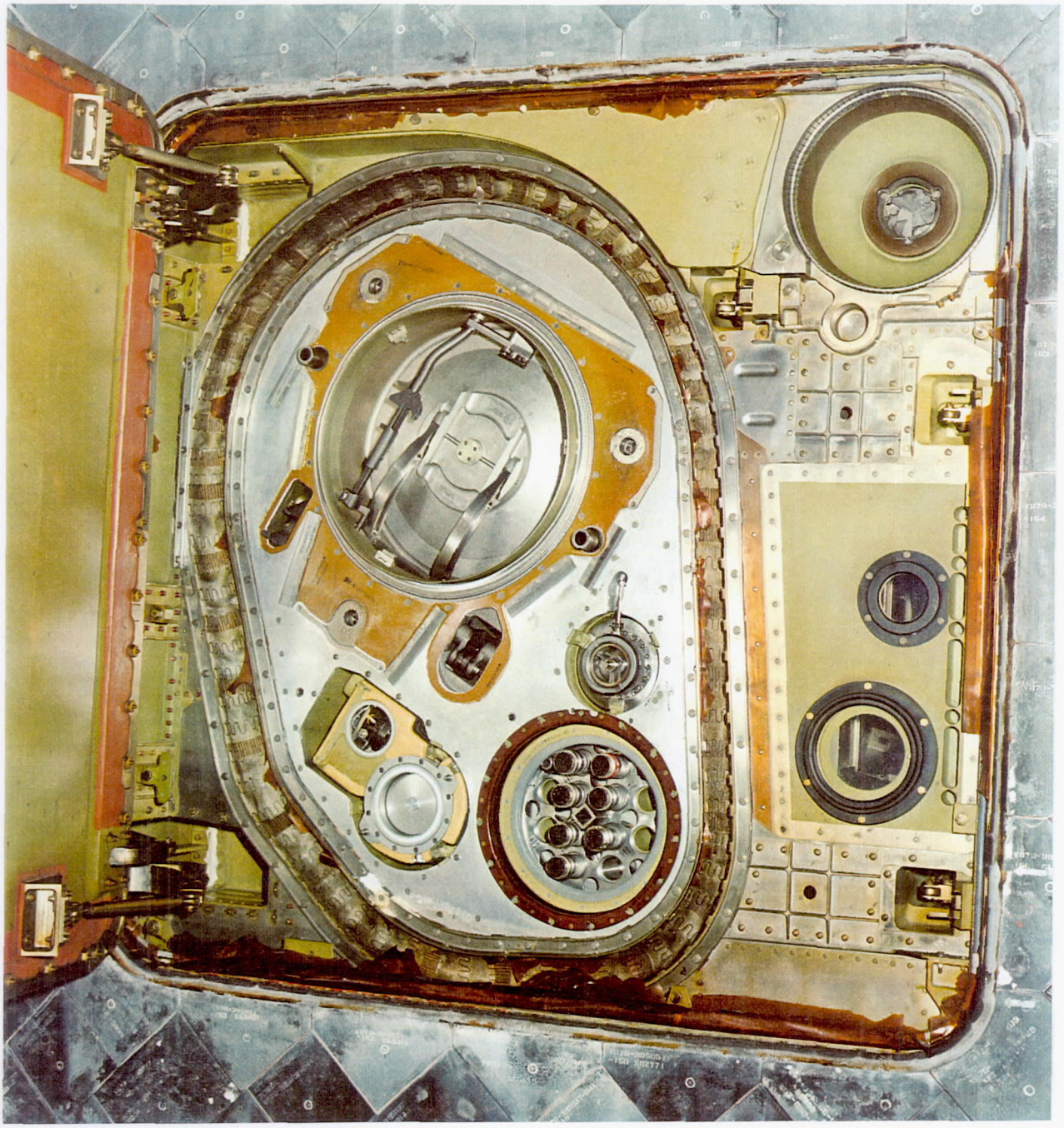
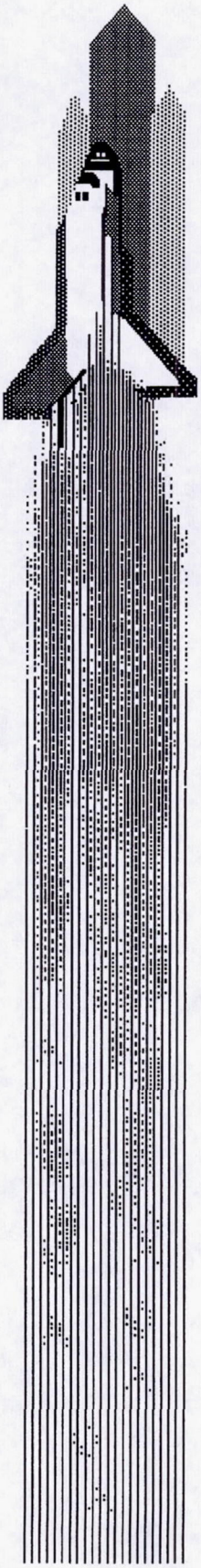


Photo 21: LH2 ET/ORB Umbilical

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

image science & analysis group
nasa-jsc



Space Science Branch

STS-102 Summary of Significant Events

April 23, 2001

image science & analysis group
nasa-jsc

Space Shuttle
STS-102 Summary of Significant Events

Project Work Order - SN3CS

Approved By

Lockheed Martin

Jon Disler (by MWS)
Jon Disler, Project Analyst
Image Science and Analysis Group

Michael W. Snyder
Michael Snyder, Project Manager
Image Analysis Projects

Robert W. Payne
Robert W. Payne, Department Manager
Basic and Applied Research Department

NASA

Greg Byrne
Greg Byrne, Lead
Image Science and Analysis Group
Space Science Branch

Prepared By

Science, Engineering, Analysis, and Test Operation
Lockheed Martin Space Operations
for
Space Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

Tables and Figures

Figure 2.2.1 (A)	Large Flexible Debris Near LH2 Umbilical Prior to Liftoff	A7
Figure 2.2.1 (B)	Flexible Piece of Debris near North Side of LO2 TSM Prior to Liftoff	A8
Figure 2.2.1 (C)	Debris from SRB Flame Ducts at Liftoff (Camera E222)	A9
Table 2.2.3	SSME Mach Diamond Formation Times	A10
Figure 2.2.3	Barrier Material from LH2 TSM Falling During Liftoff (Camera E18)	A11
Figure 2.3.2 (A)	Comparison of STS-106 and STS-102 ET EO-3 Unretracted Bolts	A13
Figure 2.3.2 (B)	35mm Umbilical Well Camera View of ET Intertank	A15
Figure 2.3.3	Crew Handheld Images of the External Tank	A17
Table 2.4	Landing Event Times	A18
Table 2.5	Main Gear Midpoint Landing Sink Rate	A19
Figure 2.5	Main Gear Midpoint Landing Sink Rate	A20

1 STS-102 (OV-103): Film/Video Screening and Timing Summary

1.1 Screening Activities

1.1.1 Launch

The STS-102 launch of Discovery (OV-103) from Pad 39B occurred on Thursday, March 8, 2001 at approximately 067:11:42:09.014 UTC as seen on camera E9. SRB separation occurred at approximately 11:44:13.5 UTC as seen on camera KTV4B.

On launch day, 23 of the 24 expected videos were received and screened. Camera ET208 was not received. No timing data was received on the second engineering replays containing the long range tracking videos ET204, ET207, ET212, and ET213. Therefore, the times for ascent events such as debris and SSME exhaust flare sightings were not determined from video.

Twenty launch films were screened and a report was sent to the Shuttle Program distribution on March 11, 2001. Twenty-two additional films were received for contingency support and anomaly resolution. Film E208 was not received.

No anomalous events were seen during the review of the STS-102 launch videos and films that were elevated to the Launch + 4 Day KSC, JSC, MSFC Film/Video Analysis Teams Consolidated Film Review Report. No anomalous events were seen during the review of the STS-102 landing films and the on-board films of the External Tank that were elevated to the Landing + 3 Day KSC, JSC, MSFC Film/Video Analysis Teams Consolidated Film Review Report. (These reports consolidate the multi-center post flight photo reviews into a single list of observations for engineering review. This integrates the photo review process into the IFA / PRACA process to ensure that the identified observations are assessed and dispositioned prior to the next flight per established problem reporting criteria.)

The 16mm umbilical well cameras did not fly on OV-103 during STS-102. The 35mm umbilical well TPS camera film and the crew handheld still photography and video of the External Tank were acquired. See Section 2.3.

1.1.2 On-Orbit

No unplanned on-orbit Shuttle support tasks were requested.

Pre-planned real-time analysis support was provided to the ISS AF-5A.1 Space Station photographic and television external survey. The Space Station image analysis support will be documented in the AF-5A.1 Imagery Overview Report.

1.1.3 Landing

Discovery made a night landing on runway 15 at the KSC Shuttle Landing Facility on March 21, 2001 at 07:31:41.3 UTC. Ten landing videos with actual landing times were received. However, the engineering landing replay videos did not image the vehicle until after the Orbiter had touched down. Eight landing films were received.

STS-102 (OV-103) Film/Video Screening and Timing Summary

The landing touchdown appeared normal. The drag chute deploy sequence appeared normal on the landing imagery. Using available video including NASA-Select, no anomalous events were seen during the Orbiter approach, landing, and landing rollout.

Post landing, a sink rate analysis of the STS-102 main landing gear was performed for the main gear touchdown. See Section 2.5.

According to the pre-mission agreement, the STS-102 landing films were not screened due to budgetary constraints.

2 Summary of Significant Events

2.1 KSC, JSC, MSFC Film / Video Analysis Teams Consolidated Film Review Reports

No anomalous events were noted during the screening of the STS-102 launch and landing films. No anomalies were reported in the Launch +4 day or the Landing +3 day KSC, JSC, MSFC Film / Video Analysis Teams Consolidated Film Review Reports.

2.2 Other Launch Observations

2.2.1 Debris from SSME Ignition through Liftoff

A small, dark-colored unidentified piece of debris was seen falling aft along the right side of the RSRB before SSME ignition. It is possible that this debris was carried with the FSS deluge water by the northwest winds. (Camera E5)

Similar to previous missions, multiple pieces of ice debris and vapors were seen falling from the ET/Orbiter umbilicals along the -Z side of the body flap during SSME ignition through liftoff. Umbilical ice debris was seen to contact the Orbiter LH2 umbilical well doorsill during SSME ignition (11:42:06.12 UTC). This event has been seen on previous missions. No damage to the launch vehicle was detected. (Cameras OTV109, OTV154, OTV161, OTV163, E1, E5, E17, E31, E34, E54)

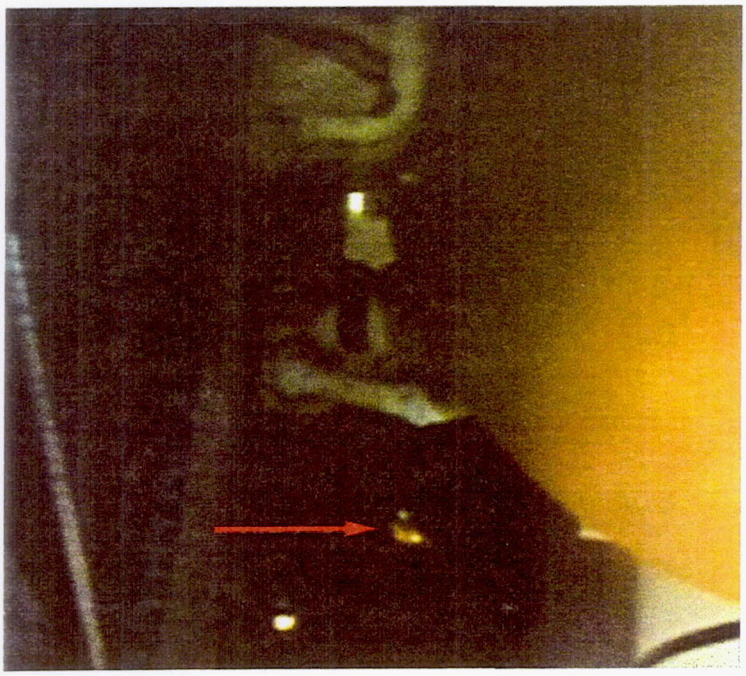


Figure 2.2.1 (A) Large Flexible Debris Near LH2 Umbilical Prior to Liftoff

A large piece of light-orange-colored flexible debris was seen falling from below the LH2 umbilical prior to lift off (11:42:07.3 UTC). This debris may have been a piece of umbilical well purge barrier material. (Camera OTV154)

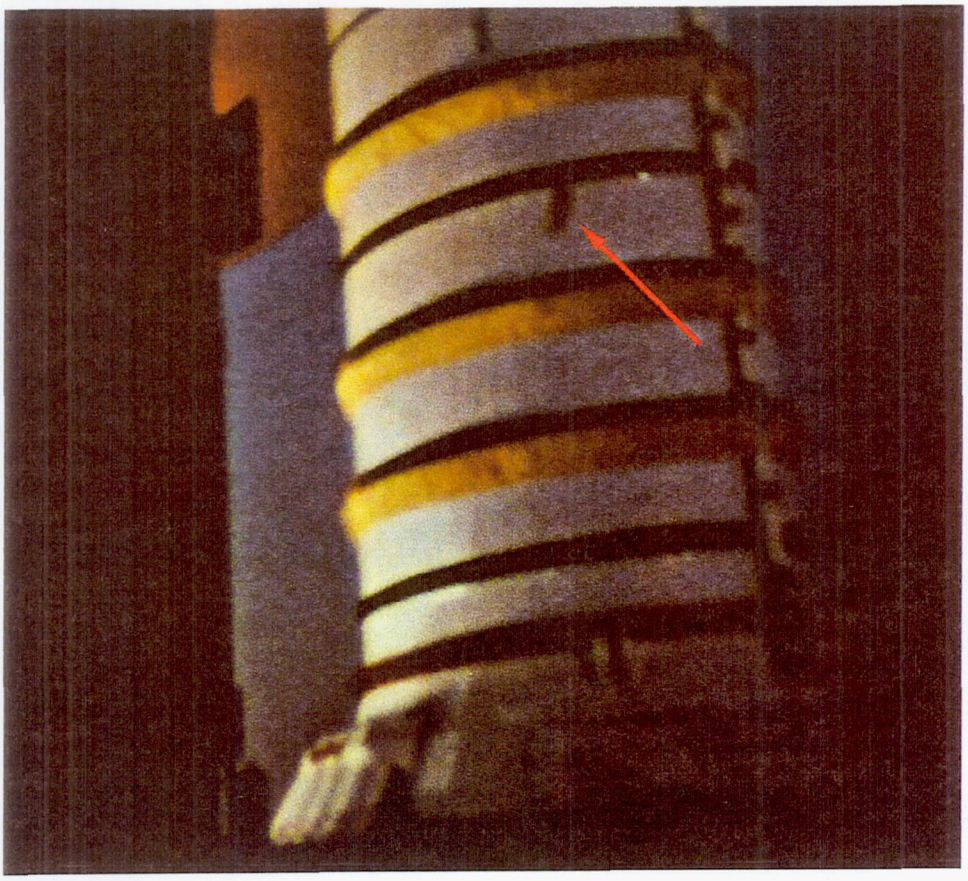


Figure 2.2.1 (B) Flexible Piece of Debris near North Side of LO2 TSM Prior to Liftoff

On camera E2, a large flexible piece of umbilical purge barrier material debris seen on the north side of the LO2 TSM, traveled near the RSRB, and fell aft to the deck of the MLP (11:42:08.891 UTC). See Figure 2.2.1 (B). During liftoff, a piece of ET / Orbiter umbilical purge barrier material was seen to be partially detached before breaking away and falling aft (Camera E31, 11:42:10.794 UTC). The remaining visible umbilical purge barrier material was seen flapping against the Orbiter tiles. The flapping of this material could have resulted in the tile damage found post-landing near the ET / Orbiter umbilicals. After the roll maneuver, another large piece of umbilical purge barrier material was seen falling aft of the vehicle. Umbilical purge barrier material debris has been seen during ascent on previous missions. (Cameras E2, E4, E5, E31, E54, E207, E223)

An unidentified large, thin, square-shaped, dark-colored piece of debris was seen falling along the LSRB near holddown post M-8 prior to SRB ignition. This debris was not seen to contact the launch vehicle. (Camera E14)

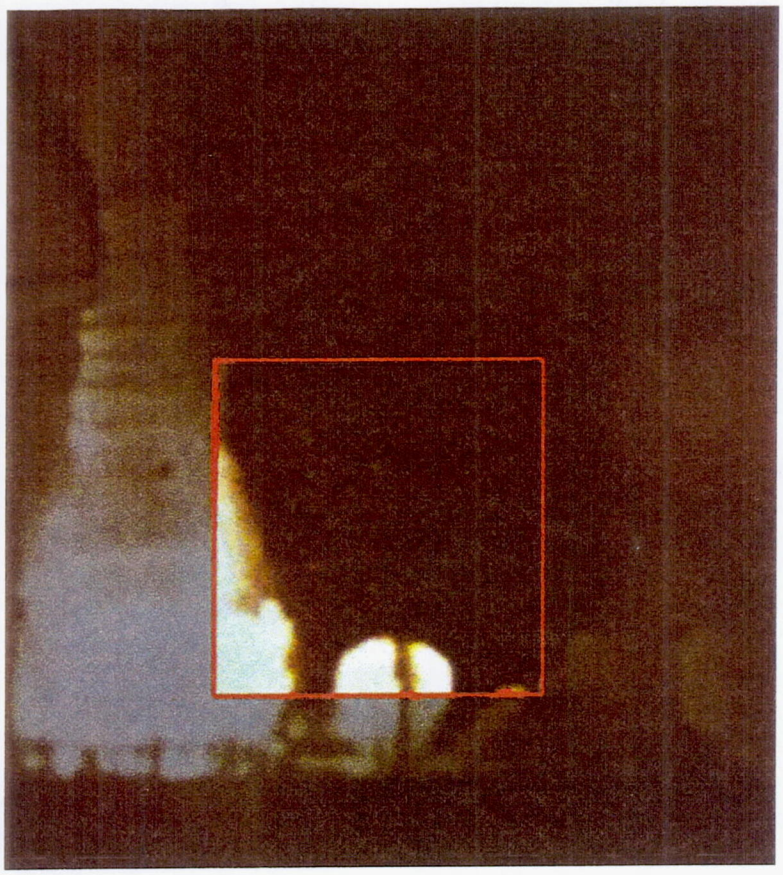


Figure 2.2.1 (C) Debris from SRB Flame Ducts at Liftoff (Camera E222)

Typical of many previous missions, several light-colored pieces of debris were seen traveling from the area of both the right and left SRB flame ducts (probably SRB throat plug material or SRB aft skirt instafoam) in a northerly direction away from the launch vehicle after SRB ignition (11:42:10.838 UTC). A larger, light-colored debris object was seen on the north side of the vehicle at a higher elevation than the other debris. This object was concluded to have been a bird. On camera E1, a piece of probable throat plug material, seen near the left SRB aft skirt, traveled in a +Y direction toward the RSRB and the LO2 TSM. On camera E5, a piece of probable SRB throat plug material was seen moving from near the aft end of the SRB's toward the body flap at liftoff. A single piece of light-colored debris (probable SRB aft skirt instafoam) was seen near the RSRB aft skirt area moving away from the vehicle during liftoff. None of the debris was seen to contact the launch vehicle. (Cameras OTV163, E1, E4, E36, E63, E222, E223, E224)

2.2.2 Debris During Ascent

As observed on previous missions, multiple pieces of debris (umbilical ice and RCS paper) were seen near the SSME exhaust plume and falling aft of the launch vehicle during ascent. Also during ascent, several pieces of light-colored debris (probably umbilical ice) were seen along the -Z side of the body flap. Examples are:

Cameras E207, E222, E224 - Multiple pieces of umbilical ice and RCS paper were seen aft of the vehicle after the roll maneuver.

Camera E212 - RCS paper debris was seen near the vertical stabilizer (frames 3940, 4130)

Cameras ET207, E222 - Multiple pieces of umbilical ice debris were seen near the trailing edge of the body flap. (11:42:40.951 UTC)

As on previous missions, light-colored debris was seen exiting the SRB exhaust plumes during ascent. The pieces of debris exiting the SRB exhaust plumes during the majority of the ascent were probably instafoam from the aft end of the SRB's. The more dense appearing debris near the time of tail-off, just prior to SRB separation, were probably SRB slag debris. (Cameras KTV4B, ET207, E207, E212, E223)

2.2.3 Mobile Launch Platform (MLP) Events

Large areas of frost were seen on the External Tank TPS prior to lift off, through tower clear and into the roll maneuver. After the roll maneuver the frost was no longer visible. (Cameras OTV170, KTV4B, E1, E4, E34, E52, E54, E222, E223)

The SSME ignition appeared normal on the high-speed engineering films. However, during SSME start-up the SSME Mach diamonds did not form in the expected sequence (3, 2, 1). Instead, the Mach diamonds formed in a 2, 3, 1 sequence. The times for the Mach diamond formation given in Table 2.2.3 are from film E19. (Cameras E20, E76, OTV151)

SSME	TIME (UTC)
SSME #2	11:42:05.834
SSME #3	11:42:05.889
SSME #1	11:42:06.183

Table 2.2.3 SSME Mach Diamond Formation Times

Orange vapor (possibly free burning hydrogen) was seen forward of the SSME rims, near the base of the vertical stabilizer, and forward of the trailing edge of the OMS pods during SSME ignition (11:42:04.0 UTC). Orange vapor forward of the SSME rims has been seen on previous mission films and videos. (Cameras OTV171, E1, E4, E5, E17, E18, E19, E20, E36, E63, E76)

Flexing of the SSME #2 Dome Mounted Heat Shield (DMHS) and the base heat shield near SSME #2 was detected during SSME ignition (11:42:05.42 UTC). This movement has been seen on previous mission films. (Camera E18)

As reported by KSC, the stream of sparks from the LH2 south radial outward firing hydrogen ignitor (used to prevent the build up of hydrogen near the SSME's) was not continuous. (Camera E20)

Typical of previous missions, small areas of tile surface coating material erosion were seen on the base heat shield outboard of SSME #3 (11:42:04.7 UTC), on the base heat shield outboard of SSME #2, and on the base of the left RCS stinger (11:42:05.48 UTC) prior to liftoff. (Cameras E17, E18, E19, E20)

What appeared to be a partially detached piece of tape was seen on the LO2 TSM T-0 umbilical feed lines prior to liftoff. (Camera E17)

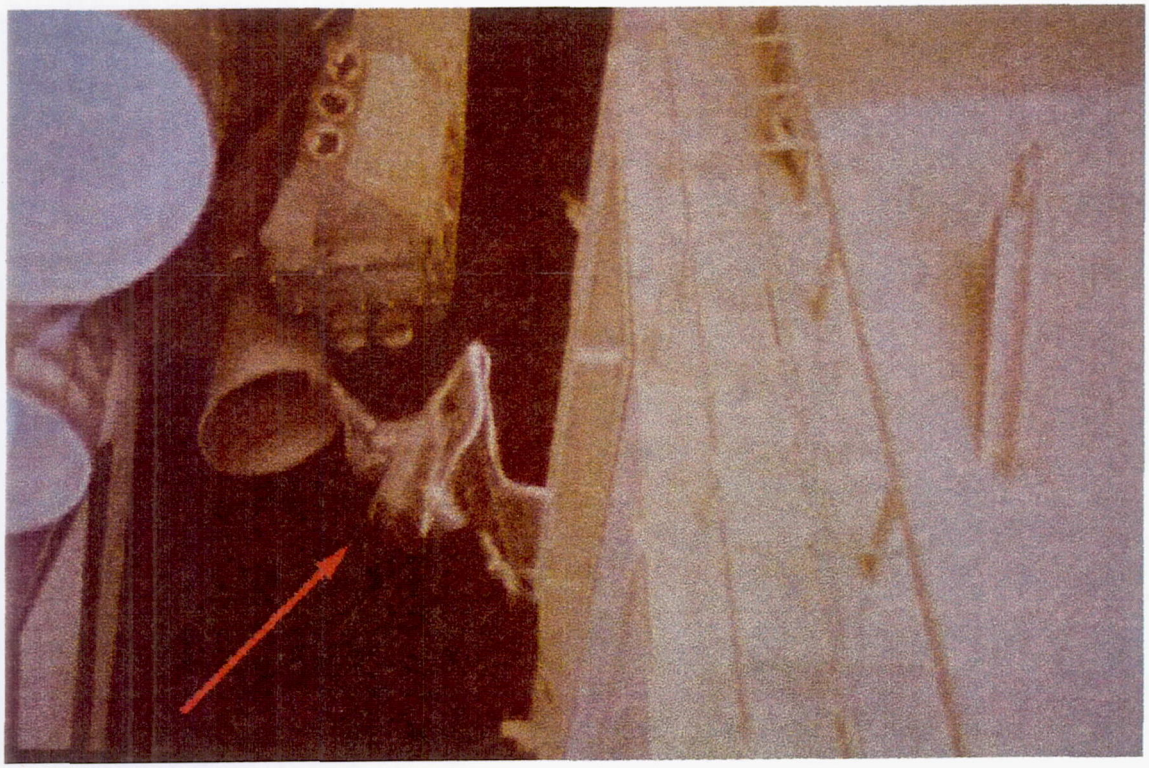


Figure 2.2.3 Barrier Material from LH2 TSM Falling During Liftoff (Camera E18)

A large, clear, piece of flexible closeout / barrier material from the LH2 TSM umbilical compartment was seen falling just after the LH2 TSM umbilical carrier had retracted. (11:42:10.421 UTC). See Figure 2.2.3. (Camera E18, E19)

SRB ignition was at 11:42:09.014 UTC based on the observation of the PIC firing at RSRB holddown post M-1. (Camera E9)

Two faint light-colored streaks, typical of previous missions, were seen extending aft of the SSME nozzles prior to liftoff. (Camera E2)

Several large pieces of flexible, water baffle debris were seen near the LSRB flame trench before becoming lost from view in the exhaust cloud during liftoff (11:42:10.846 UTC). At the same time, a dark-colored unidentified piece of debris traveled upward toward the LSRB. The debris did not strike the vehicle. (Camera E4)

A light-colored object reported by KSC to have been a NASA helicopter was seen on the west side of the launch pad after the vehicle cleared the tower (11:42:14.589 UTC). (Camera E52)

An unidentified fluid-like substance (possible water) was seen streaking down the –Y side of the LSRB during liftoff (11:42:12.015 UTC). (Camera E33)

The left and right SRB GN2 purge lines appeared wrapped, upright, and intact until they were obscured by exhaust plumes at 11:42:10.664 UTC (left purge line) and 11:42:11.046 UTC (right purge line). (Cameras E8, E13)

2.2.4 Ascent Events

Several light-orange-colored flares were noted in the SSME exhaust plume during ascent on the intermediate and long range tracking camera films. Often on previous mission imagery, debris has been seen contacting the SSME exhaust plume resulting in visible flares. Usually this debris is RCS paper. (On STS-26 and STS-101, debris that resulted in very large orange-colored flares was determined to have been tile material.) Examples of flares seen on STS-102 are:

E207	Frames 1671, 1947
E212	Frame 1761
E222	11:42:38.035, 11:42:40.425 - 11:42:43.271 UTC
E223	Frames 3215, 3435, 3620, 3930, 4180, 4640
ET207	
ET213	

Flares in the SSME exhaust plumes have been seen on previous missions films and videos.

The body flap motion seen on STS-102 was less apparent than that seen on STS-97 and STS-98. This may be at least partially due to the soft focus of the long range tracking views (due to atmospheric haze or film processing). Unless requested, no follow-up analysis will be attempted because of soft focus and the relatively small amount of detectable body flap motion. (Camera E207, frames 1671 - 3768)

A partially detached piece of RCS paper was seen on the +Z side of the right RCS stinger during early ascent. (Camera ET207)

A new procedure was implemented by the Shuttle Program to fire the forward RCS thrusters during SRB separation in order to help keep the Orbiter windows free of exhaust particle hazing.

The effects of the firing of the forward RCS were visible in the exhaust plumes near the forward end of the Orbiter. (Camera E207)

Orange vapors from the early OMS-2 assist burn were visible approximately 10.1 seconds after SRB separation (Cameras E207 frame 7825, E212 frame 8028, E223 frame 13060).

2.3 Onboard Photography of the External Tank (ET-107)

2.3.1 16mm Umbilical Well Camera Films

The two 16mm umbilical well camera films were disabled preflight because of the investigation into an electric short problem.

2.3.2 35mm Umbilical Well Camera Film

The external tank appeared in excellent condition on the 35mm handheld imagery and the 35 mm umbilical well imagery of the STS-102 External Tank (ET-107). No anomalous conditions on the ET were noted. One special interest observation was noted:

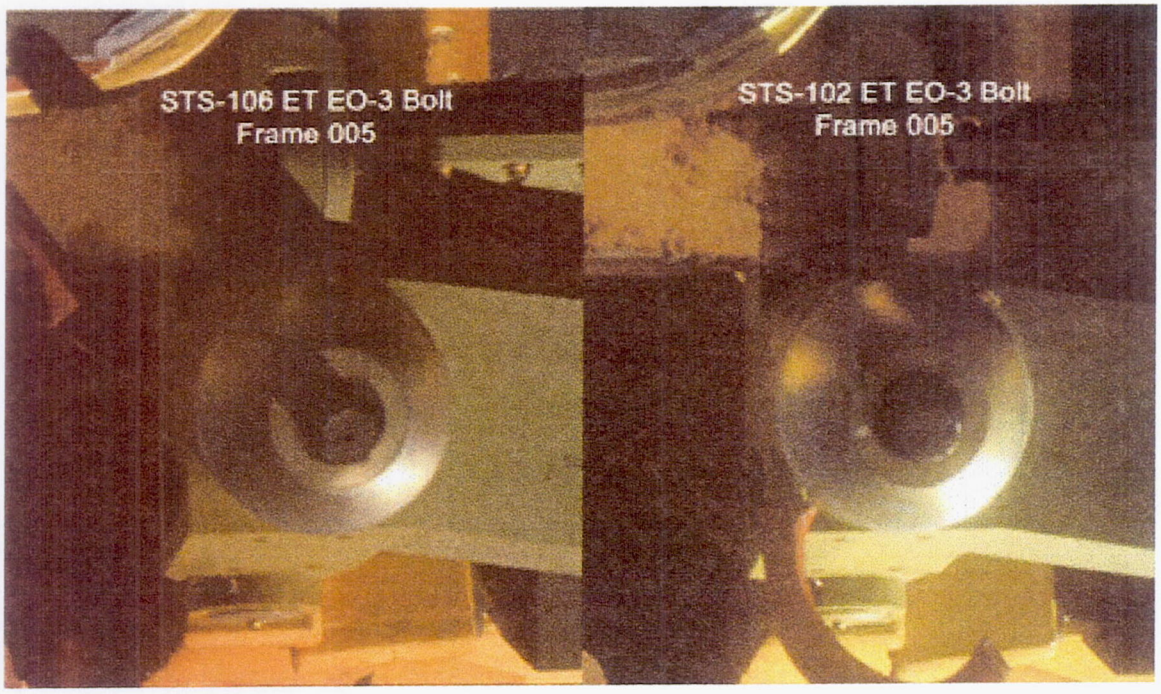


Figure 2.3.2 (A) Comparison of STS-106 and STS-102 ET EO-3 Unretracted Bolts

The separation bolt between the ET and the Orbiter at the aft end of the ET (EO-3 fitting near the liquid oxygen umbilical) was confirmed not to be fully retracted as viewed from the umbilical film. See Figure 2.3.2 (A), image on right. Comparing successive frames, a lateral motion of the bolt was determined to have been present. The EO-3 bolt appeared similar to the protruded EO-3 bolt seen on the STS-106 umbilical well camera film. See Figure 2.3.2 (A), image on left. An attempt to measure the length of the STS-102 unretracted bolt using a parallax method with pairs

of images showing the bolt at slightly different angles was unsuccessful because of the bolt motion. An animated movie (gif image) showing the STS-102 bolt motion was created. Also, a previous mission (STS-106) gif image showing a similar protruding bolt with no apparent motion was created for comparison purposes. The STS-102 bolt was clearly "free floating", and not rigid. A rigid bolt is a cause for concern since it could interfere with the proper separation between the ET and the Orbiter. Therefore, this event was not identified as an anomaly. (A Shuttle Program investigation of the STS-106 bolt extension was previously conducted in October, 2001.)

Minor TPS chipping and very small divots (typical of previous missions) were seen on the aft LO2 feedline flanges and on the aft bracket over the press lines. Small, shallow areas of TPS erosion and divoting were visible on the forward flange of the +Y ET/Orbiter thrust strut. Typical ablation and divoting of the TPS on the vertical section of the +Y electric cable tray adjacent to the LO2 umbilical were detected. The small "popcorn" divots typically seen on the ET aft dome on previous mission views, were not seen on the visible portions of the ET-107 aft dome.

The face of the LO2 umbilical carrier plate appeared to be in excellent condition (no indication of damaged or missing lightning contact strips was detected).

The red-colored purge seal on the EO-3 ball joint fitting was partially detached but still in the field of view. Detached or missing seals from the EO-3 ball joint fitting were noted on previous mission film screenings.

A small light-colored, irregular-shaped piece of debris was visible near the +Y thrust strut and the aft ET cross beam. The identity of the debris was not confirmed, although the debris appeared to have been a piece of frozen hydrogen.

The +Z LH2 tank TPS was in shadow and too dark for analysis. However, the visible portions of the +Y LH2 tank TPS appeared to be in excellent condition.

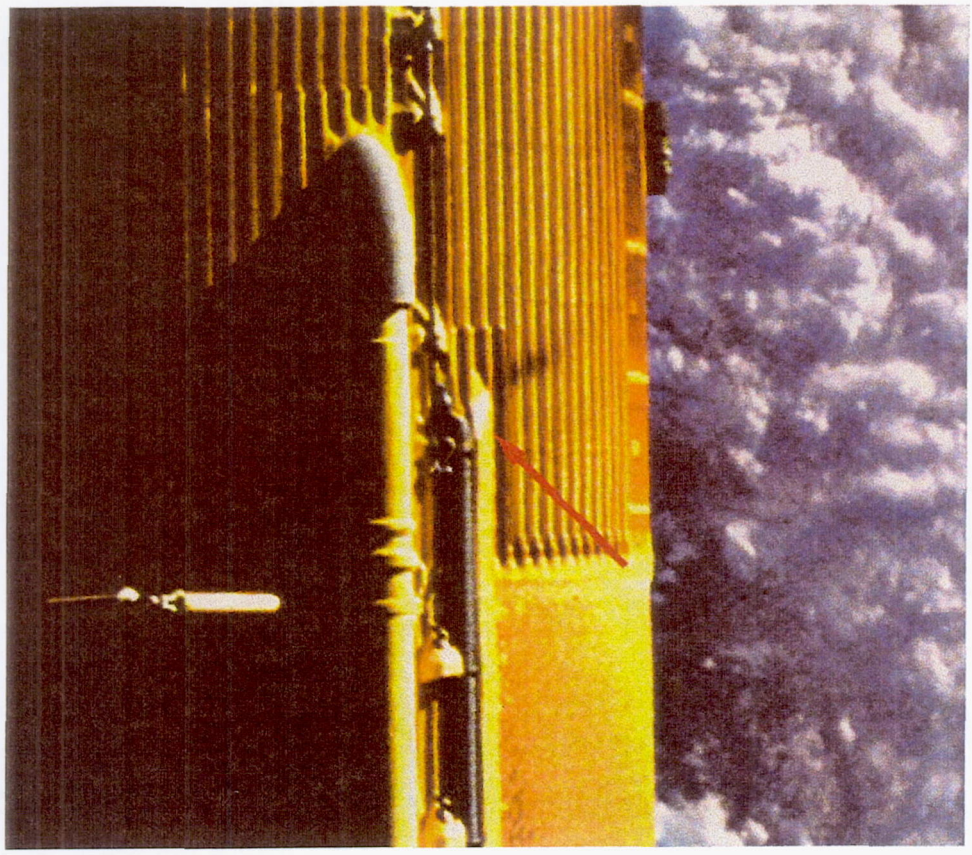


Figure 2.3.2 (B) 35mm Umbilical Well Camera View of ET Intertank

An approximately nine inch long white-colored mark (possible TPS ablation) was visible on the forward end of the PAL ramp (just aft of the forward LO2 feedline bellows). See Figure 2.3.2 (B).

The visible portion of the +Z/+Y ET Thrust Panel appeared in excellent condition and no divots were seen on the TPS between the +Y forward SRB attach and the LO2 feedline. The separation burn scar from the RSRB on the +Y ET TPS appeared normal. As expected, the left (-Y) SRB thrust panel was not imaged on this film.

The LH2 tank-to-intertank flange closeout in the –Y direction from the LO2 feedline and the bipod jack pad close outs were obscured from view by shadow. No divots were seen on the visible, non-shadowed, intertank rib heads forward of the bipod. No divots were seen on the LH2 tank-to-intertank close-out flange in the +Y direction from the LO2 feedline.

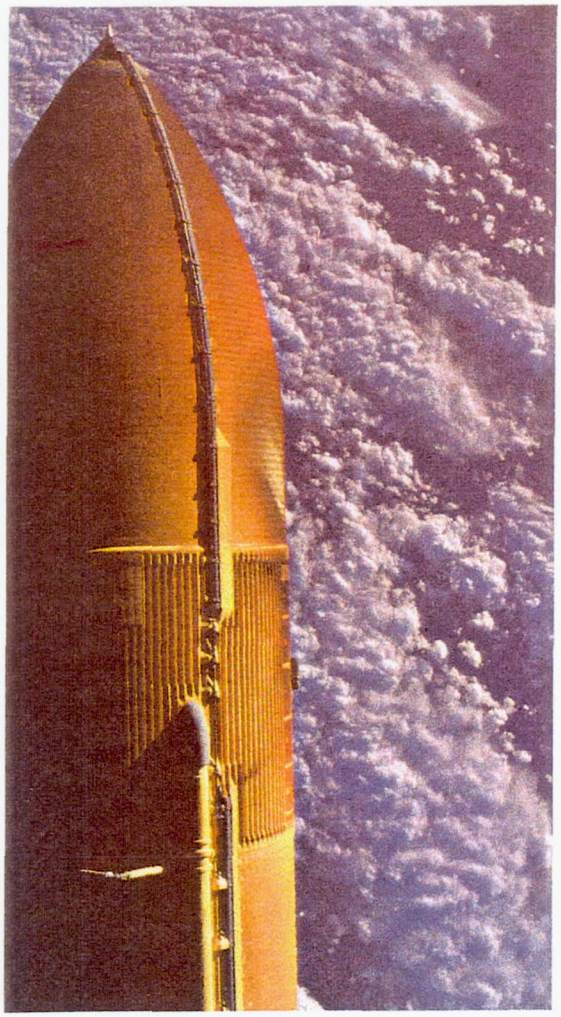


Figure 3.2.3 (C) 35mm Umbilical Well Camera View of Forward ET

The LO2 tank / Ojive TPS appeared to be in excellent condition. The nose of the ET appeared free of damage and the nose cap appeared in good condition. The aero friction and aero heating marks seen on the TPS just aft of the nose cone appeared normal and were less than that typically seen on previous missions.

Notes: The 35mm umbilical well camera film (roll 379) was recorded from the Orbiter LO2 umbilical well. Fifty-nine excellent quality frames imaging the ET were acquired. The +X translation maneuver was performed on STS-102 to facilitate the imaging of the ET with the umbilical well camera.

2.3.3 ET Handheld Photography

Crew handheld views of the nose, the aft dome, both limbs (+/- Y sides), and the far side (-Z) of the ET were obtained. The ET was fully illuminated with very little shadowing. The distance of the ET from the Orbiter was calculated to be approximately 3 km on the first photographic frame

acquired. The minimum resolvable object size on the handheld film at 3 km was estimated to be approximately nine inches.

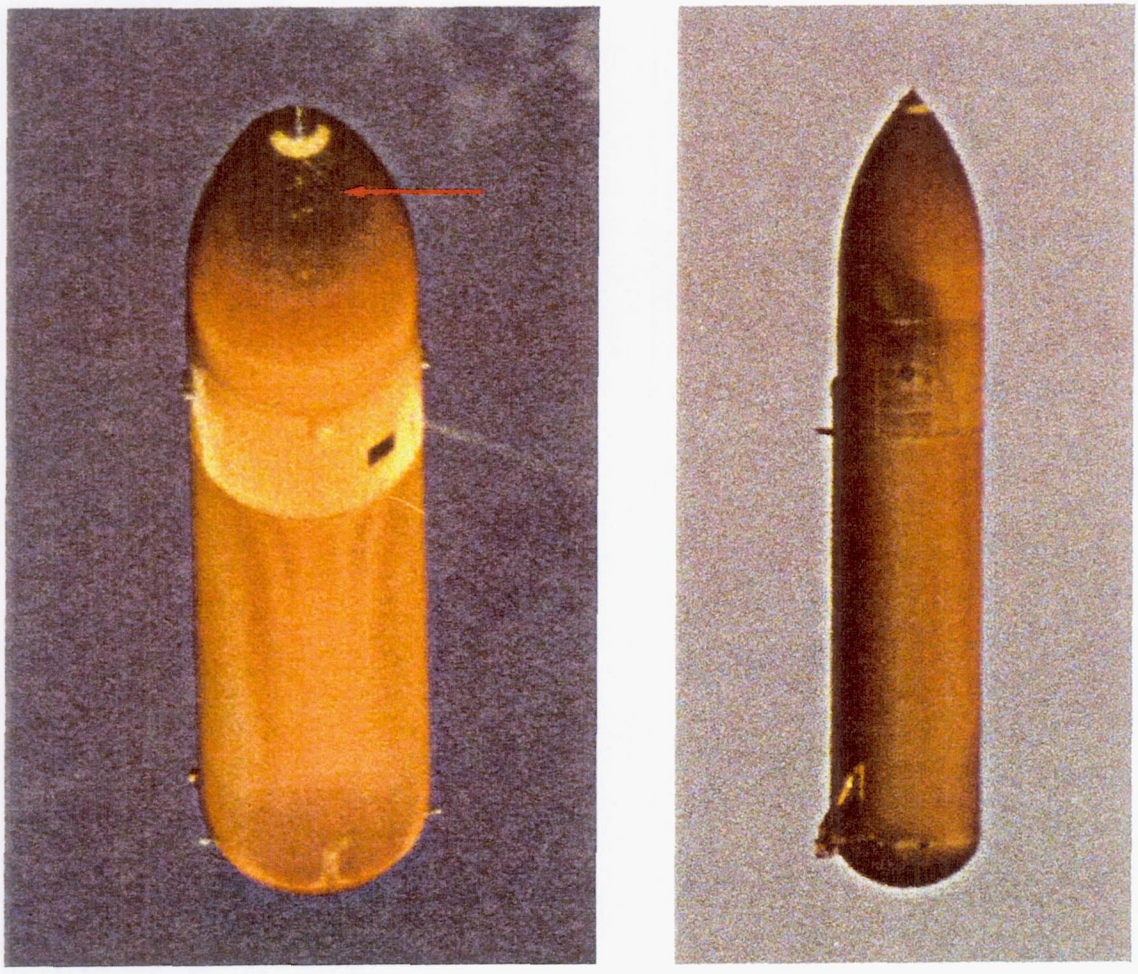


Figure 2.3.3 Crew Handheld Images of the External Tank

The normal SRB separation burn scars and aero-heating marks were noted on the intertank and nose TPS of the ET. The LO2 tank / Ojive TPS appeared to be in good condition. However, there were several light-tone marks on the –Z side of the nose that appeared to be ablated TPS. See Figure 2.3.3, Crew Handheld Images of the External Tank (arrow).

The +Y ET thrust panel appeared in satisfactory condition. No significant divoting of the thrust panel TPS was confirmed from the handheld imagery. The –Y thrust panel was imaged at an oblique angle due to the attitude of the ET relative to the Orbiter when the pictures were taken. No divots were seen on the visible portion of the –Y thrust panel.

No divots or unusual marks were seen on the LH2 tank TPS and the ET aft dome.

Notes: Thirty-six excellent quality handheld pictures of the External Tank were acquired using the handheld 35mm Nikon F5 camera with a 400mm lens (roll 311). Timing data is present on

the film with the first picture being taken at 19:01 (minutes : seconds) MET. The astronauts performed a manual pitch maneuver from the heads-up position to bring the ET into view in the Orbiter overhead windows for the handheld photography.

2.3.4 ET Handheld Video

The handheld video was good quality. The video of the ET was acquired using the new PD-100 camcorder. The tumble rate of the ET was measured to be approximately 12 degrees per second from the video. This rate was greater than the ET tumble rate measured on STS-101 and STS-106 and was probably due to the later MET when the ET was imaged. No venting was seen from the ET intertank gaseous hydrogen vent on the STS-102 video.

2.4 Landing Events Timing

The time codes from videos were used to identify specific events during the screening process. The landing event times are provided in Table 2.4.

STS-102 Landing and Drag Chute Event Times from Video:

Event Description	Time (UTC)	Camera
Main gear door opening	~080:07:31:19.821	NASA Select Video
Left main gear tire touchdown	~080:07:31:41.286	SLF North
Right main gear tire touchdown	~080:07:31:41.676	NASA Select Video
Nose gear tire touchdown	~080:07:31:51.953	NASA Select Video
Drag chute initiation	~080:07:31:54.656	NASA Select Video
Pilot chute at full inflation	Not Observed	NA
Bag release	Not Observed	NA
Drag chute inflation in reefed configuration	Not Observed	NA
Drag chute inflation in disreefed configuration	~080:07:32:01.436	KTV5L
Drag chute release	080:07:32:30.845	KTV11
Wheel Stop	~080:07:33:01.008	KTV11

Note: ~ Denotes that the time shown is approximate.

Table 2.4 Landing Event Times

2.5 Landing Sink Rate Analysis

Image data from the centerline camera at the approach end of runway 15 was used to determine the landing sink rate of the main gear. In the analysis, data from approximately one second of imagery immediately prior to touch down for each of the landing gear was considered. Data points defining the main gear struts were collected on every frame (50 frames of data during the last second prior to touch down with respect to each landing gear. The speed of Camera E7 was measured to be 49.1 frames per second). An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's y-axis. The distance between the main gear struts (272 inches) was used as a scaling factor. The main gear midpoint height above the runway was calculated by the change in vertical difference between the main gear struts and the reference point on the runway. The left and right main gear heights were calculated from their corresponding gear strut and the reference point on the runway. A trendline for each of the main gear and the midpoint between the main gear was determined considering the height of the Orbiter above ground with respect to time. Sink rate equals the slope of each regression line.

The main gear sink rate for STS-102 landing at one second, at half a second, and at a one quarter of a second are provided in Table 2.5. The left main gear sink rate and the midpoint between the main gear are relative to left main gear touch down. A plot describing the sink rate for the midpoint between the main gears is shown in Figure 2.5.

Time Prior to Touchdown	Main Gear Sink Rate	Estimated Error (1σ)
1.00 Sec.	0.7 ft/sec	± 0.1 ft/sec
0.50 Sec.	0.7 ft/sec	± 0.1 ft/sec
0.25 Sec.	1.1 ft/sec	± 0.3 ft/sec

Table 2.5 Main Gear Midpoint Landing Sink Rate

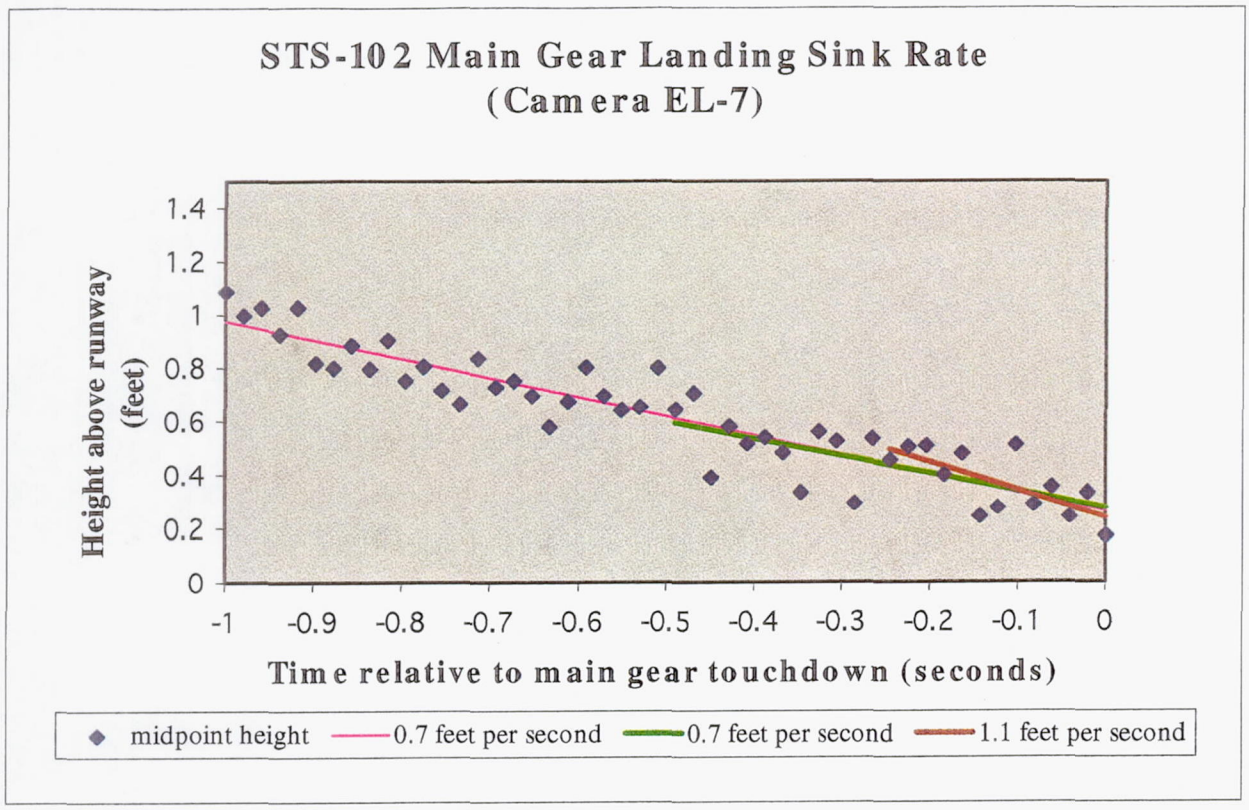


Figure 2.5 Main Gear Midpoint Landing Sink Rate

The maximum allowable main gear sink rate values are 9.6 feet / second for a 212,000 lb. vehicle and 6.0 feet/second for a 240,000 lb. vehicle. The landing weight of the STS-102 vehicle was reported to be 218,304 lbs.

2.6 Other

2.6.1 Normal Events

Normal events observed included:

- elevon motion prior to liftoff
- RCS paper debris from SSME ignition through liftoff
- ET twang
- ice and vapor from the LO2 and LH2 TSM T-0 umbilical prior to and / after disconnect
- multiple pieces of ET/Orbiter umbilical ice debris falling along the body flap during liftoff
- vapor off the SRB stiffener rings
- acoustic waves in the exhaust cloud during liftoff
- debris in the exhaust cloud (including water baffle material) after liftoff
- charring of the ET aft dome
- ET aft dome outgassing
- roll maneuver
- linear optical effects
- recirculation
- SRB plume brightening
- SRB slag debris before, during, and after SRB separation

2.6.2 Normal Pad Events

Normal pad events observed included:

- hydrogen burn ignitor operation
- FSS and MLP deluge water activation
- sound suppression system water operation
- GH2 vent arm retraction
- TSM T-0 umbilical disconnect and retraction
- LH2 and LO2 TSM door closures

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

Space Shuttle Mission STS-102

Engineering Photographic Analysis Summary Report
Marshall Space Flight Center

T. J. Rieckhoff (NASA/MSFC)
M. Covan (USA)
J.M. O'Farrell (USA)

April 18, 2001
Marshall Space Flight Center,
Huntsville, AL 35812

Contents

Engineering Photographic Analysis Report for STS-102 1
STS-102 Photographic Analysis Summary: 1
Photographic Analysis Website: 1
Photographic Coverage: 1
T-Zero Times : 2
SRB Separation Timing: 2
Anomalies: 2
Observations: 3
Video Camera TV-4B: Frost on ET Acreage 3
Video Camera TV-4B: Pad Debris at SRB Ignition 4
Video Camera OTV-154: Purge Barrier Material Debris 5
Video Camera OTV-171: Free Burning Hydrogen at SSME Ignition 6
Video Camera ET-207: Streak in SSME Plumes 7
Film Camera E7: InstaFoam Debris 8
Film Camera E11: Instafoam Debris 9
Film Camera E11: Tangle of Water Bag Ropes 10
Film Camera E14: Launch Pad Debris 11
Film Camera E18: Debris from Tail Service Mast 12
Film Cameras E19 and E20: Streak in SSME Plumes 13
Film Camera E20: Ice On SSME Eyelids 14
Film Camera E9: Circular Shaped Debris 15
Film Camera E222: Debris Streak 16
Umbilical Well 35mm Still Film Camera: External Tank TPS 17
Umbilical Well 35mm Still Film Camera: Protruding EO-3 Interface Bolt 18
Astronaut Hand Held Video Camera: External Tank +Y Thrust Panel 19
Astronaut Hand Held Video Camera: External Tank -Z Side 20
Individual Camera Assessments: 21
Video Camera Assessments 21
Film Camera Assessments 21

Figures

Figure 1. Frost on ET Acreage 3
Figure 2. Pad Debris at SRB Ignition 4
Figure 3. Purge Barrier Material Debris 5
Figure 4. Free Burning Hydrogen at SSME Ignition 6
Figure 5. Debris Induced Streak in SSME Plumes 7
Figure 6. Instafoam Debris at Holddown Post M4 8
Figure 7. Instafoam Debris at Holddown Post M7 9
Figure 8. Tangle of Water Bag Ropes at Holddown Post M8 10
Figure 9. Launch Pad Debris Near Holddown Post M7 11
Figure 10. Debris from the Tail Service Mast 12
Figure 11. SSME#1 LOX Vent Cloud 13

Figure 12. Ice on SSME Eyelids 14
Figure 13. Circular Shaped Debris Object near Holddown Post M1 15
Figure 14. Debris or Vapor Streak 16
Figure 15. External Tank TPS 17
Figure 16. Protruding EO-3 Interface Bolt 18
Figure 17. External Tank +Y Thrust Panel 19
Figure 18. External Tank -Z Side 20

Engineering Photographic Analysis Report for STS-102

Launch of the one-hundred-third Space Shuttle mission, STS-102, the twenty-ninth flight of the Orbiter Discovery (OV-103), occurred March 8, 2001 at approximately 5:42 AM CST, from launch complex 39B, Kennedy Space Center (KSC), Florida. Launch time was reported as 01:067:11:42:09.004 Universal Coordinated Time (UTC) by the MSFC Flight Evaluation Team.

STS-102 Photographic Analysis Summary:

No significant out-of-family conditions or anomalous events were observed on launch film or video products covering Space Shuttle Mission STS-102.

Two unusual debris items were noted on this flight: A circular debris object near HDP M1, and a clear flexible plastic closeout/barrier sheet from the LH2 TSM Umbilical compartment.

The EO-3 Interface Bolt was observed to be protruding from the EO-3 Interface Ball Joint bore on this mission.

Photographic Analysis Website:

Further information concerning photographic analysis of this and previous space shuttle missions is available on the MSFC Engineering Photographic Analysis website at URL:

http://photo4.msfc.nasa.gov/STS/sts102/sts102.html

Information available on the MSFC Engineering Photographic Analysis website includes:

- Photographic Acquisition Disposition Document (PADD),
- Individual camera status and assessments,
- Annotated images of notable observations,
- Movies of select events, and
- Photographic Analysis Mission Summary Report (PDF format).

Photographic Coverage:

Photographic and video coverage has been evaluated to determine proper operation of the flight hardware. Video and high-speed film cameras providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), perimeter sites, Eastern Test Range tracking sites and onboard the vehicle.

Sixty-five engineering photographic products consisting of launch video, ground-based engineering films and onboard film were received and reviewed at MSFC. Camera coverage received at MSFC for STS-102 is illustrated in the following table.

	16mm	35mm	Video
MLP	19	0	4
FSS	5	0	3
Perimeter	0	7	5
Tracking	0	9	11
Onboard	0	0	0
Other	0	1	1
Totals	24	17	24

Twelve video and film products had soft focus: ET204, ET213, ET207, ET212, E207, E204, E205, E212, E213, E224, E34, and E36. Two video cameras were overexposed: ET212 and OTV150. The camera loses track of the vehicle on E54, E52, E220, and E222 and the vehicle was positioned low in the frame on film camera E59. Film processing marks were evident on film camera E223.

Received, as film from camera E6, was actually film from camera E42. An LED segment on the "minutes" line of the timing display on film camera E13 was inoperative.

T-Zero Times :

T-Zero times are regularly determined from MLP cameras that view the SRB Holddown posts, without doghouse covers, M-1, M-2, M-5, and M-6. These cameras, listed below with their corresponding Holddown Post, record the explosive bolt combustion products. Occasionally, conditions allow observation of combustion products from SRB Holddown post M-7. Although this bolt, at M-7, is partially obscured by the doghouse cover, a flash indicative of PIC firing was seen and the time recorded for this mission.

Holddown Post	Camera	Time (UTC)
M-1	E9	067:11:42:09.012
M-2	E8	067:11:42:09.011
M-5	E12	067:11:42:09.012
M-6	E13	067:11:42:09.012
M-7	E11	067:11:42:09.011

SRB Separation Timing:

SRB separation time, as recorded by observations of the BSM combustion products from long-range film camera E207, occurred at 067:11:44:13.565 UTC.

Anomalies:

No anomalous events or significant problems were noted on this mission.

Observations:

Video Camera TV-4B: Frost on ET Acreage

A large area of the External Tank was coated with frost prior to liftoff. Frost was not observed on later film/video and assumed to have sublimed or evaporated quickly during vehicle ascent.

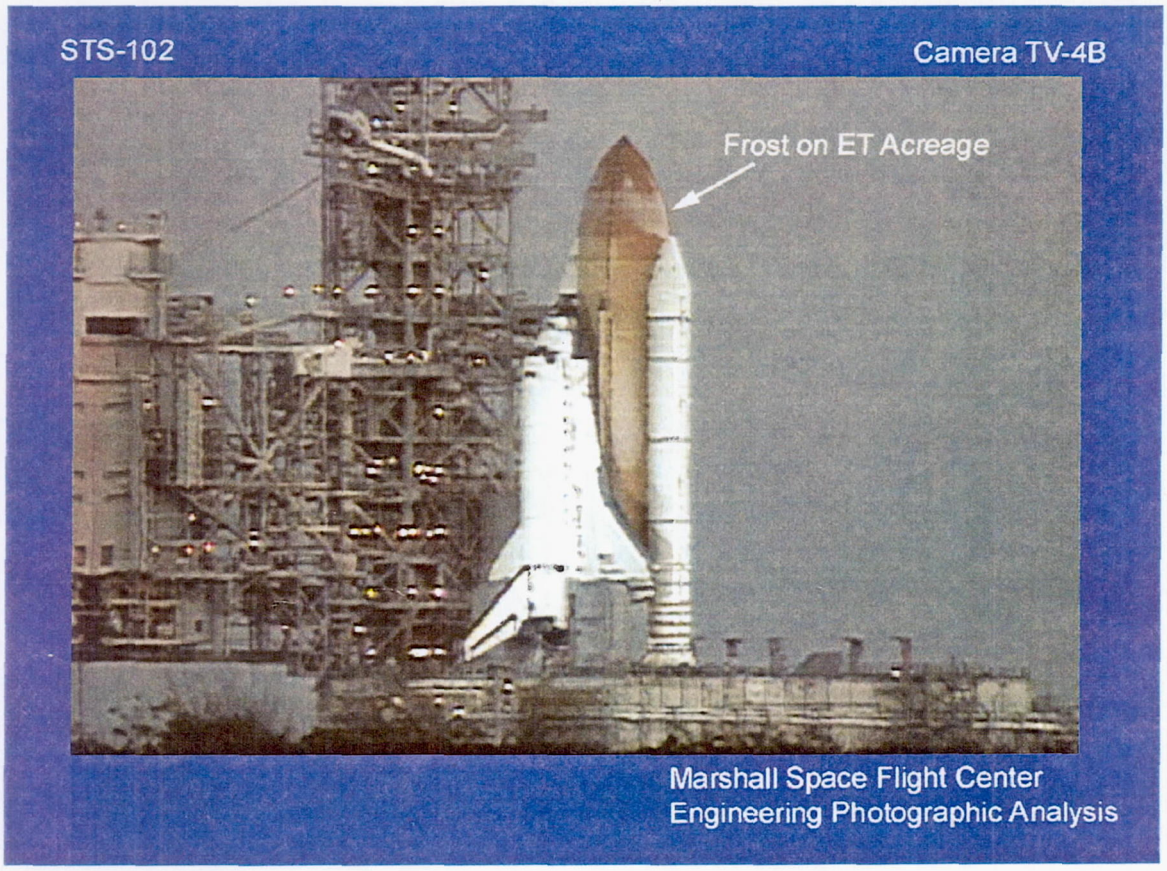


Figure 1. Frost on ET Acreage

Video Camera TV-4B: Pad Debris at SRB Ignition

Several typical launch pad debris items were observed at SRB ignition. A bird was also observed near the launch site.

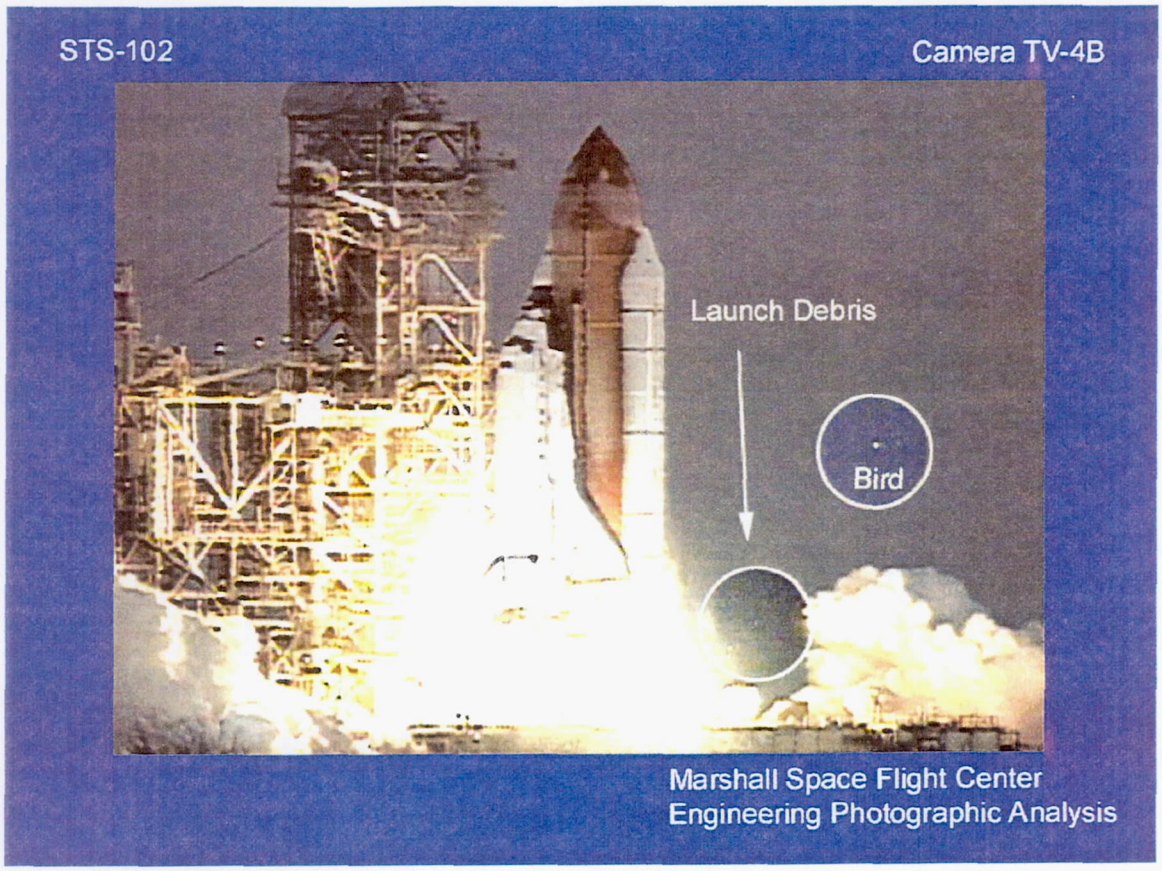


Figure 2. Pad Debris at SRB Ignition

Video Camera OTV-154: Purge Barrier Material Debris

Several pieces of purge barrier material debris were observed falling through the field of view. These appeared to come from both the LOX and LH2 17-inch disconnects.

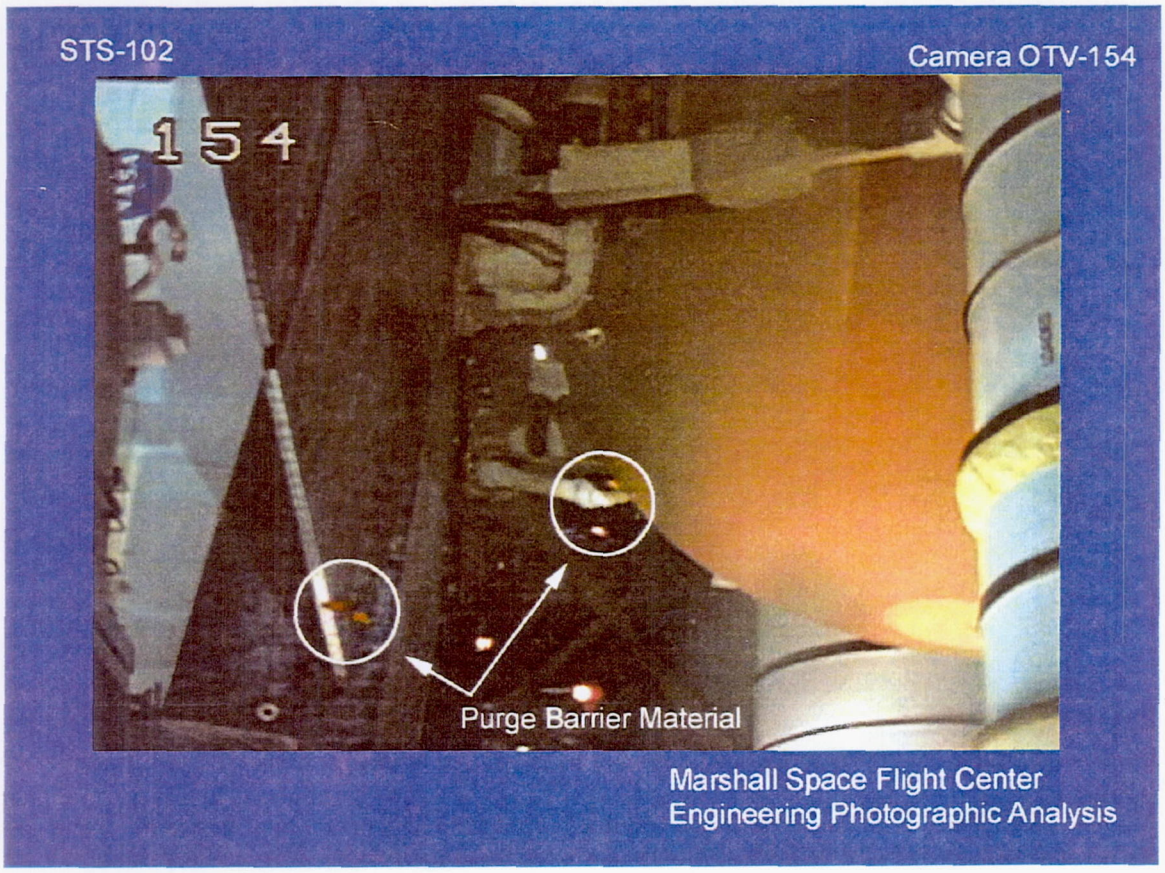


Figure 3. Purge Barrier Material Debris

Video Camera OTV-171: Free Burning Hydrogen at SSME Ignition

Free burning Hydrogen was observed at SSME ignition, extending forward of the –Y (left) OMS Pod rim. This particular phenomenon is a typical occurrence during SSME ignition and appears to be within normal limits.

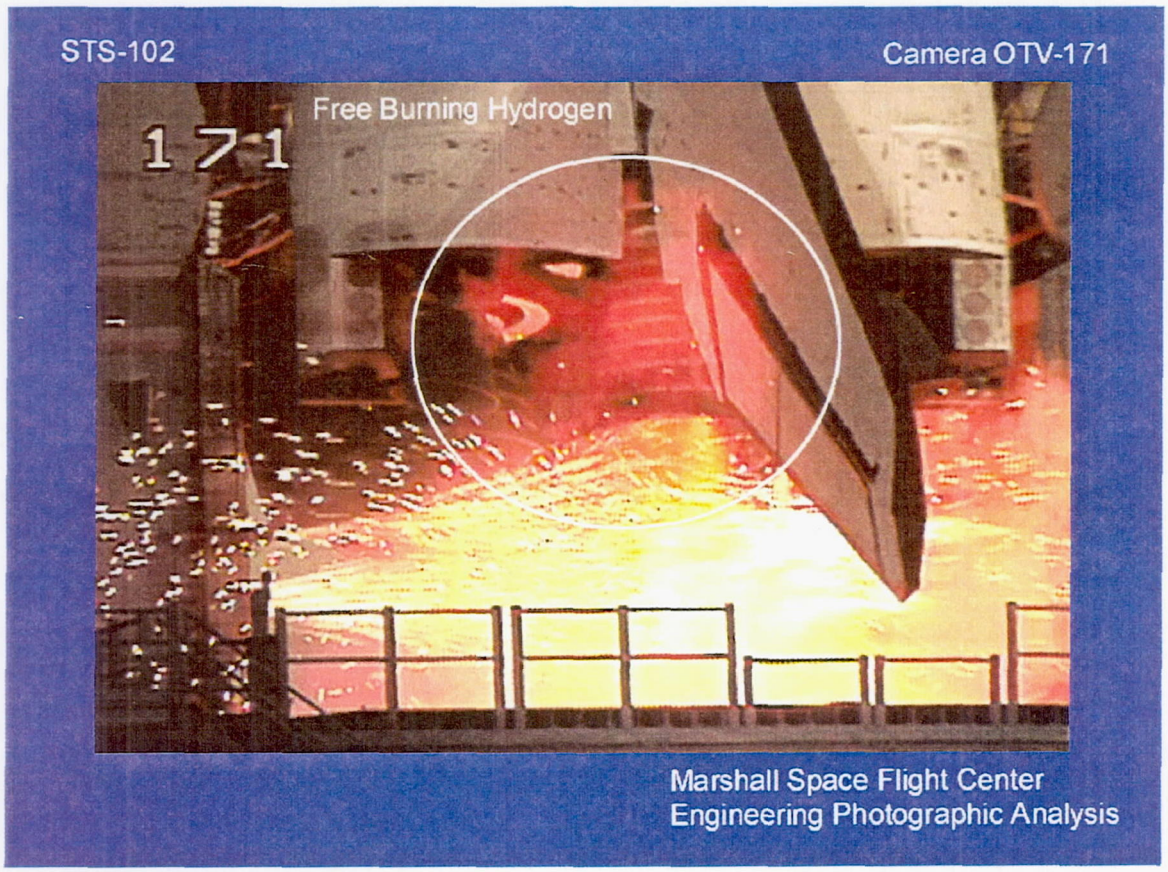


Figure 4. Free Burning Hydrogen at SSME Ignition

Video Camera ET-207: Streak in SSME Plumes

Several debris induced streaks in the SSME plumes were noted during ascent. Figure 5 illustrates one such event.

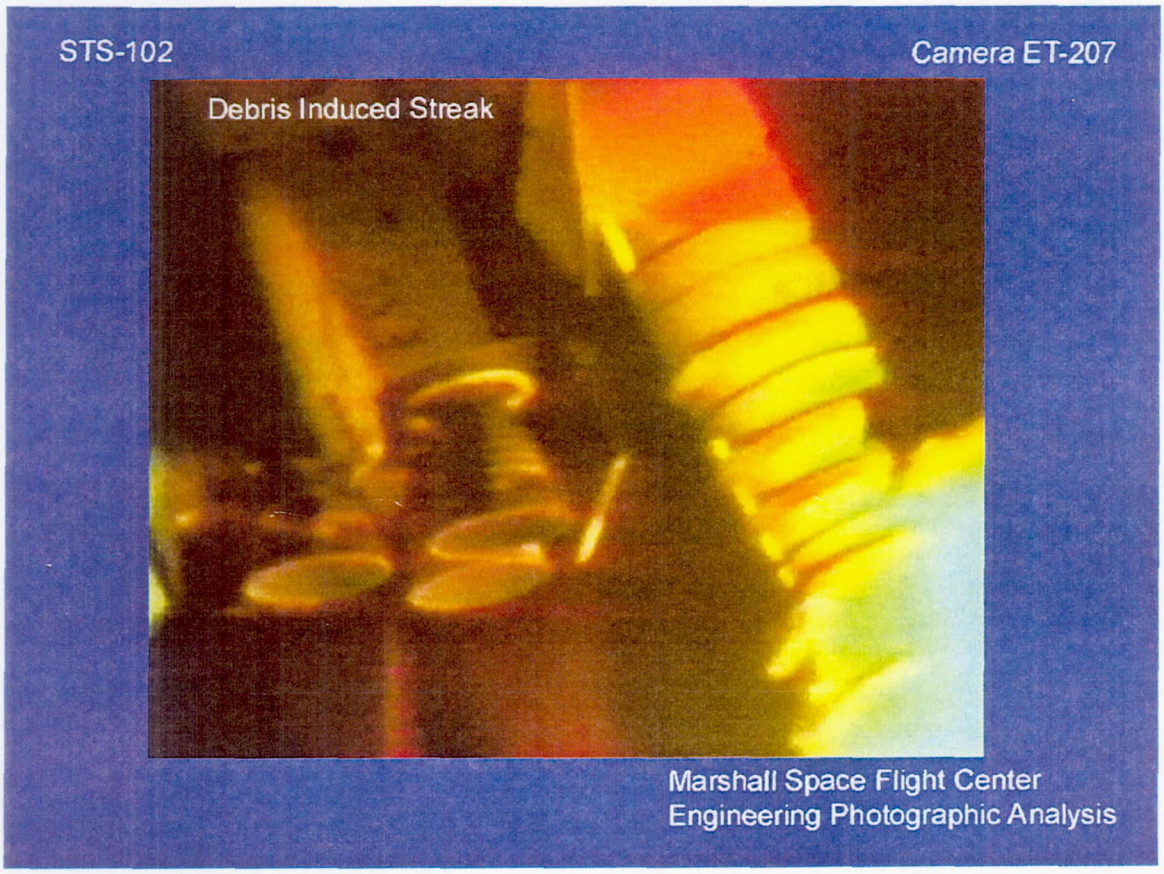


Figure 5. Debris Induced Streak in SSME Plumes

Film Camera E7: InstaFoam Debris

A notable chunk of Aft Skirt Instafoam was observed to break free after impact with the Shoe of Holddown Post M4.

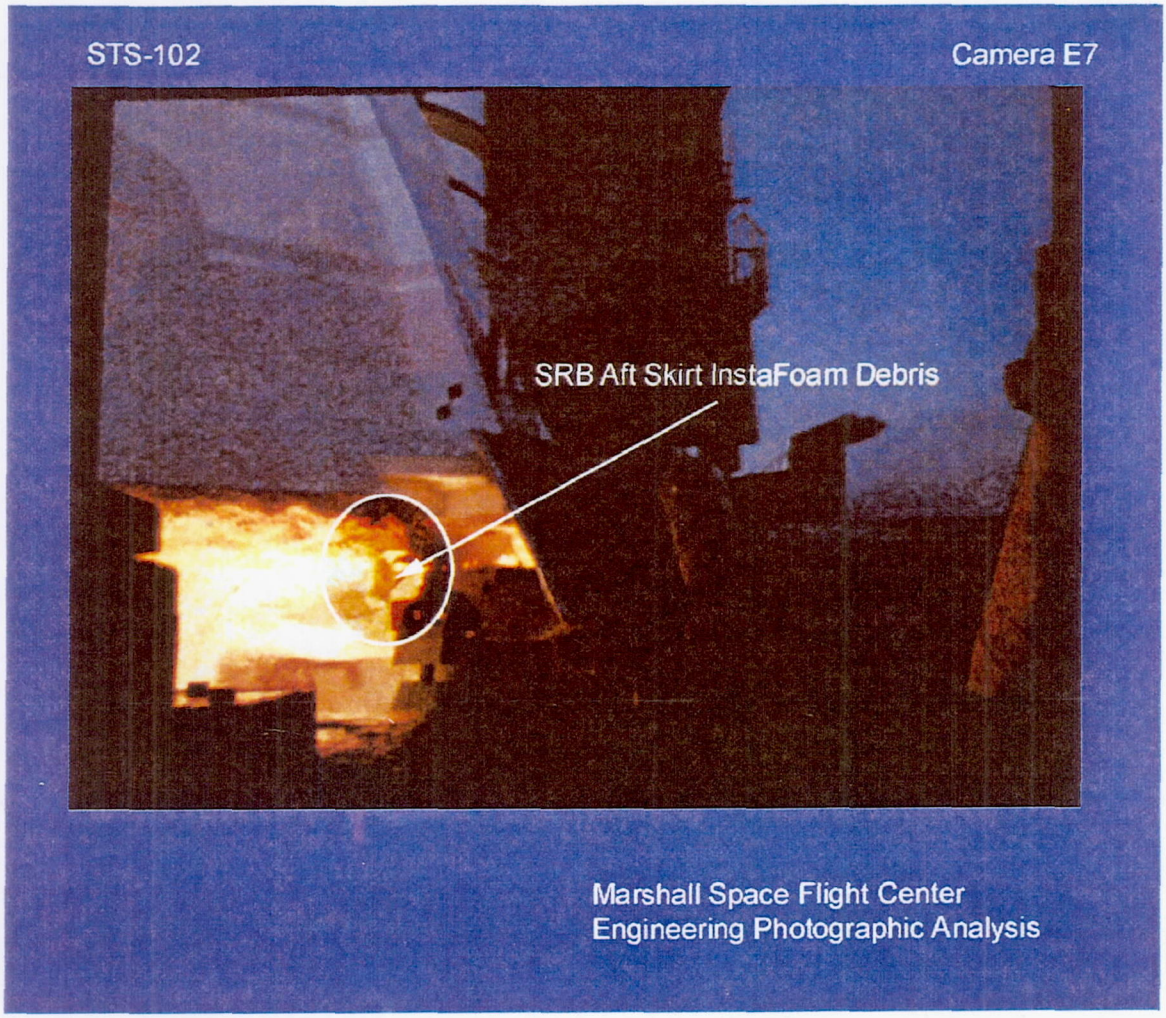


Figure 6. Instafoam Debris at Holddown Post M4

Film Camera E11: Instafoam Debris

Another notable chunk of Aft Skirt Instafoam was observed free near Holddown Post M7.

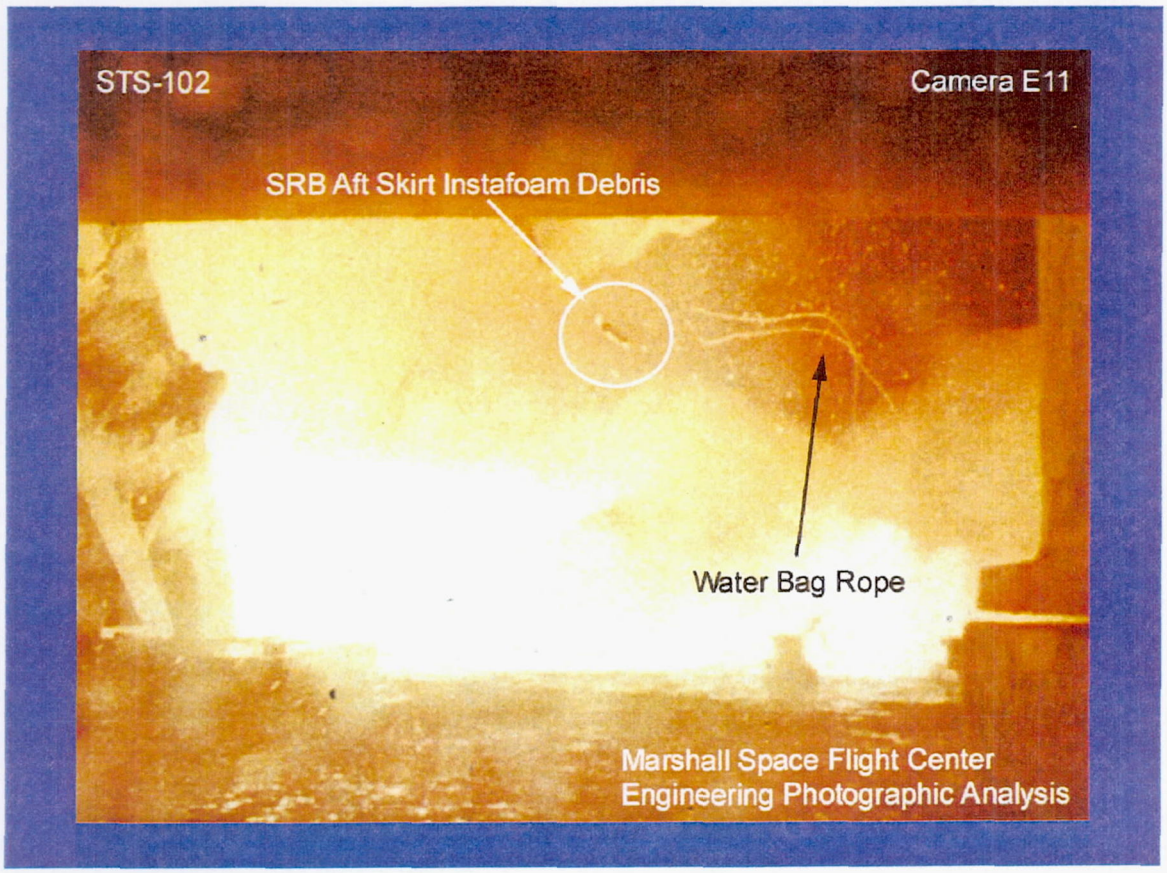


Figure 7. Instafoam Debris at Holddown Post M7

Film Camera E11: Tangle of Water Bag Ropes

Several Water Bag Ropes were ejected from the SRB flame trench in the vicinity of Holddown Post M8. Water bag ropes have been observed on many previous missions. However, the number of these ropes was greater than usual.

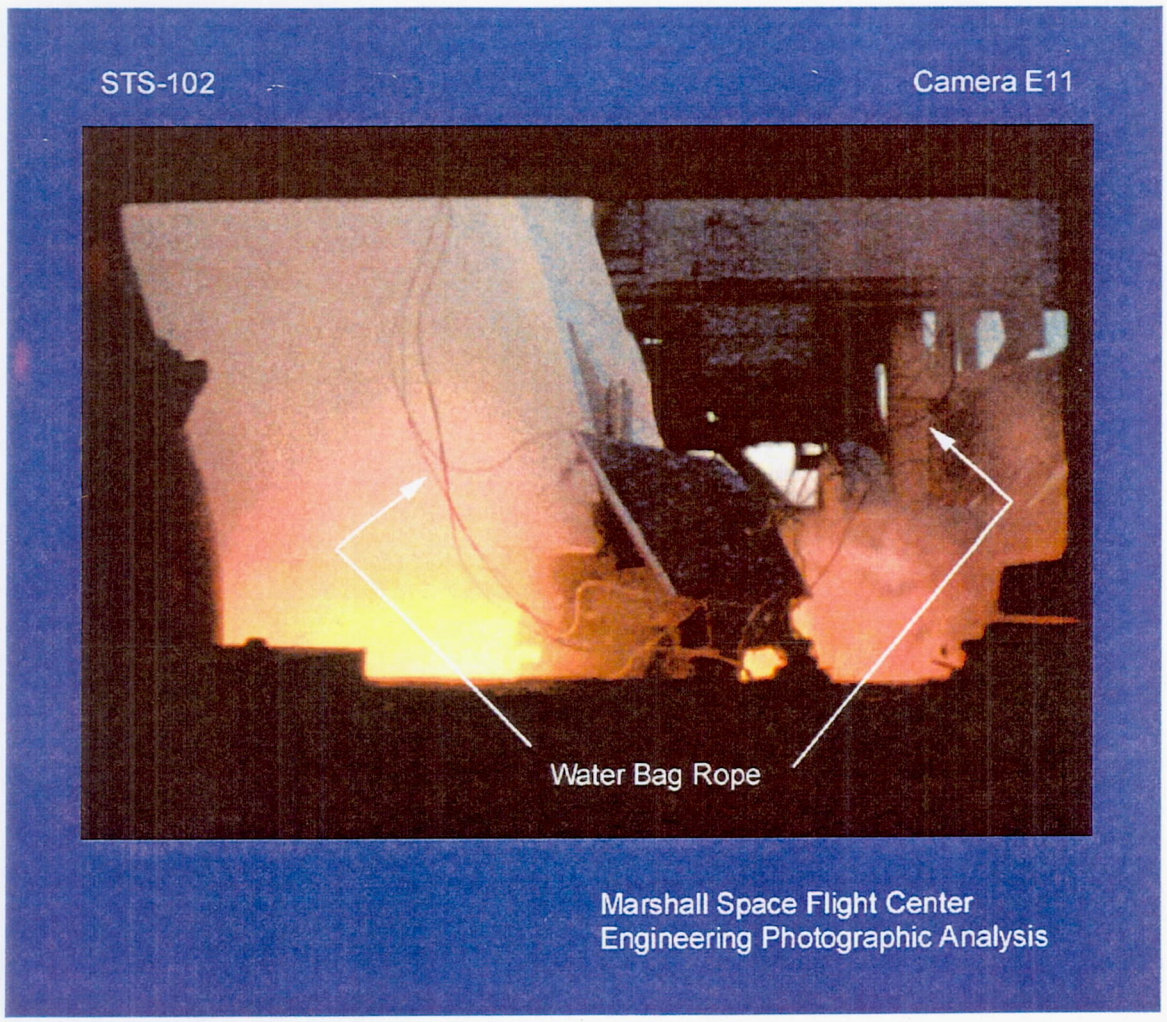


Figure 8. Tangle of Water Bag Ropes at Holddown Post M8

Film Camera E14: Launch Pad Debris

An unidentified, dark, somewhat notched debris item was observed near Holddown Post M7, falling through the field of view, just after SRB ignition. Since the object is out of focus, it is assumed to be near the camera.

Figure 9. Launch Pad Debris Near Holddown Post M7

Film Camera E18: Debris from Tail Service Mast

A sheet of plastic debris, identified as closeout/barrier material from the LH2 TSM Umbilical compartment, fell through the field of view, just after retraction of the LH2 T0 umbilical carrier. Also visible is ice around the SSME#2 eyelid.

Figure 10. Debris from the Tail Service Mast

Film Cameras E19 and E20: Streak in SSME Plumes

An unusual cloud , presumably LOX vapor originating from an SSME#1 LOX vent drain line, was observed on this mission. Possibly a shift in the winds from the SSME flame exhaust hole toward SSME#1 caused this accumulation of vapors.

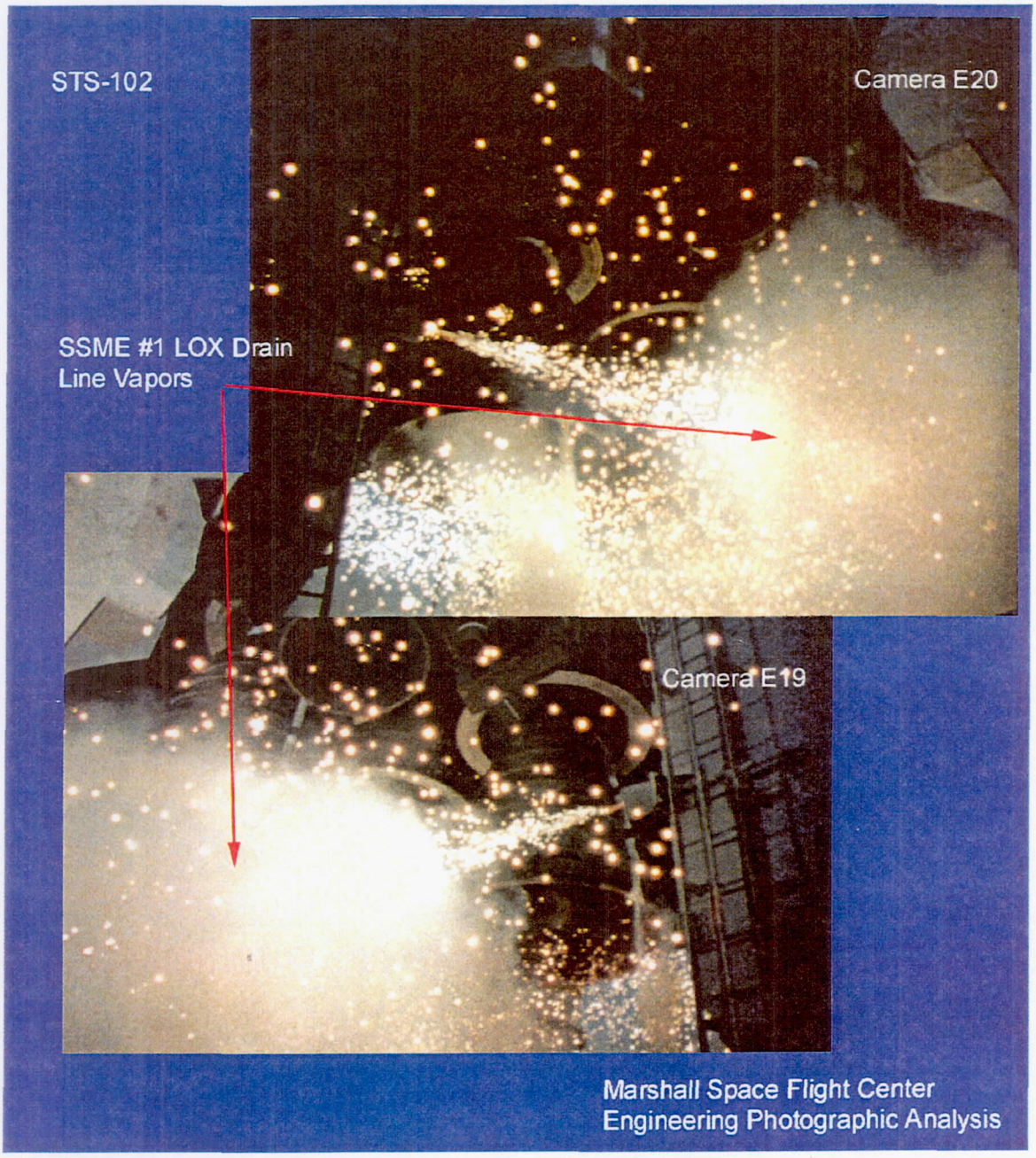


Figure 11. SSME#1 LOX Vent Cloud

Film Camera E20: Ice On SSME Eyelids

Ice or frost was observed on both SSME#2 and SSME#1 eyelids. It is uncommon to see the ice or frost on SSME#1 eyelid.

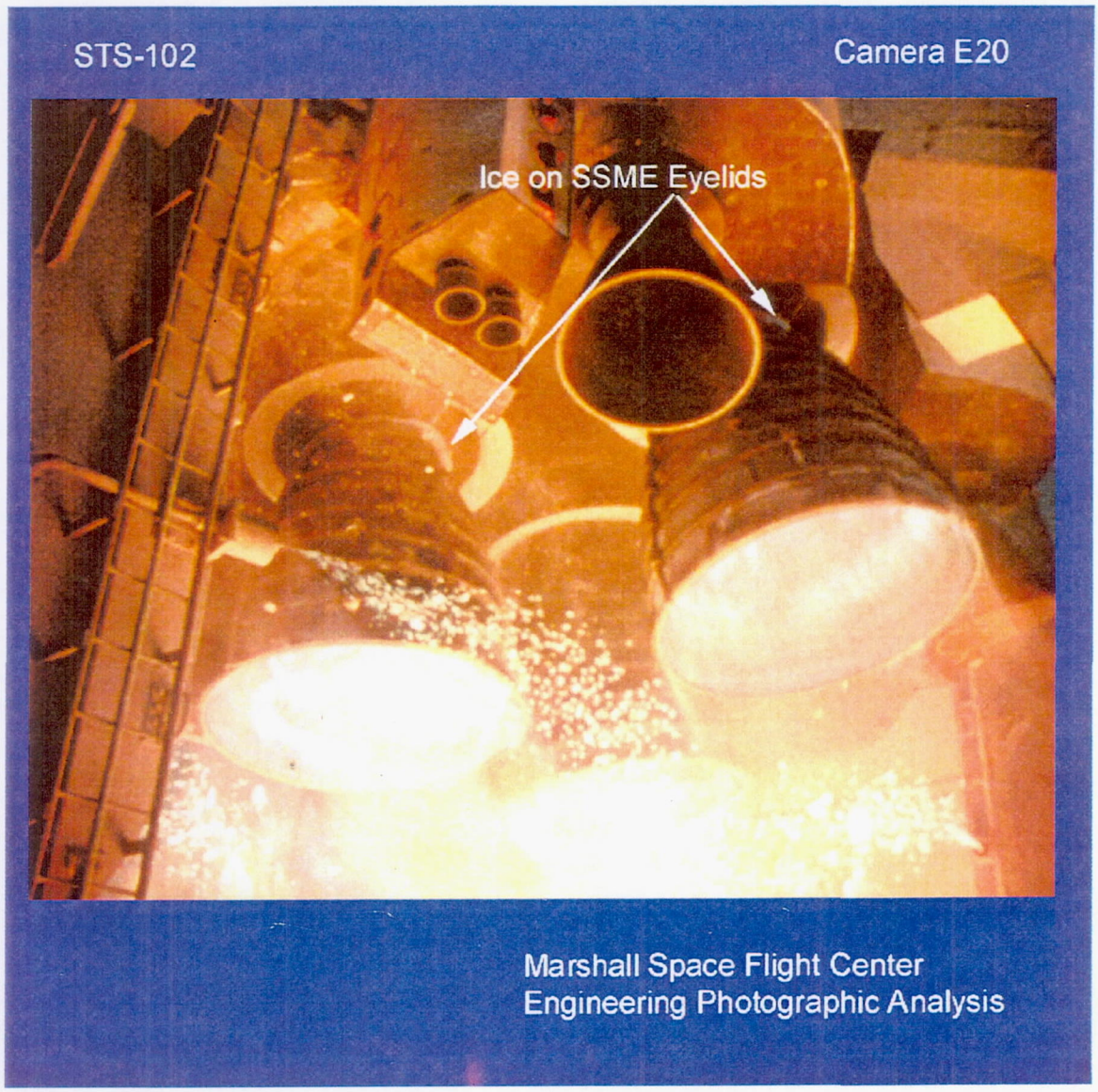


Figure 12. Ice on SSME Eyelids

Film Camera E9: Circular Shaped Debris

A circular shaped debris object was noted just after liftoff. Also, ends of threads used to bind Thermal Curtain Seams were noted.

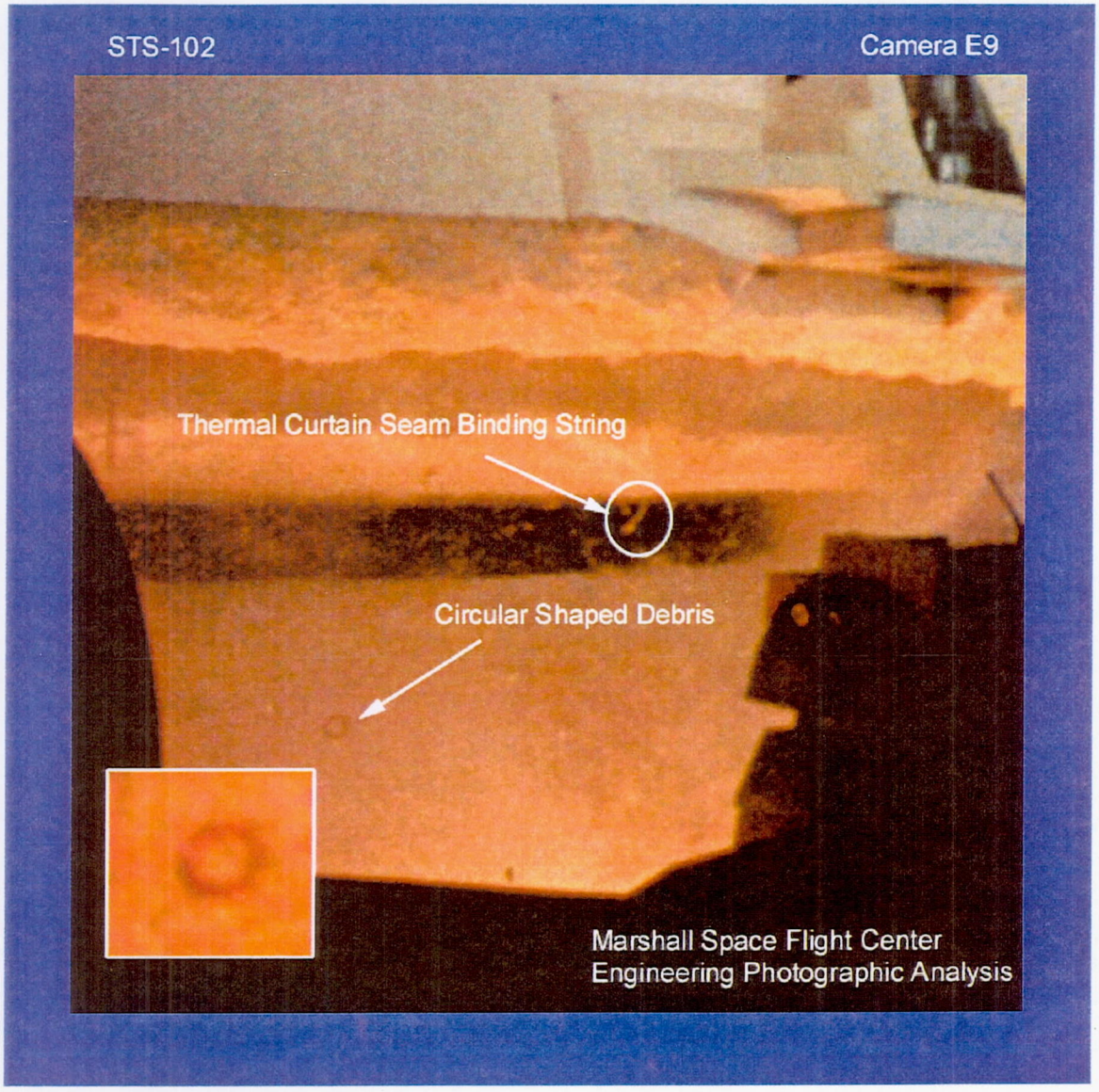


Figure 13. Circular Shaped Debris Object near Holddown Post M1

Film Camera E222: Debris Streak

A possible debris or vapor streak was observed apparently between the Orbiter Body Flap and the SRBs.

Figure 14. Debris or Vapor Streak

Umbilical Well 35mm Still Film Camera: External Tank TPS

TPS on External Tank appeared to be in very good condition. Several small ice particles were noted in the field of view between the Orbiter and the ET. Popcorning in the vicinity of the ET aft dome appeared minimal. The protruding EO-3 interface Joint Bolt may be seen in the bottom image of Figure 16.

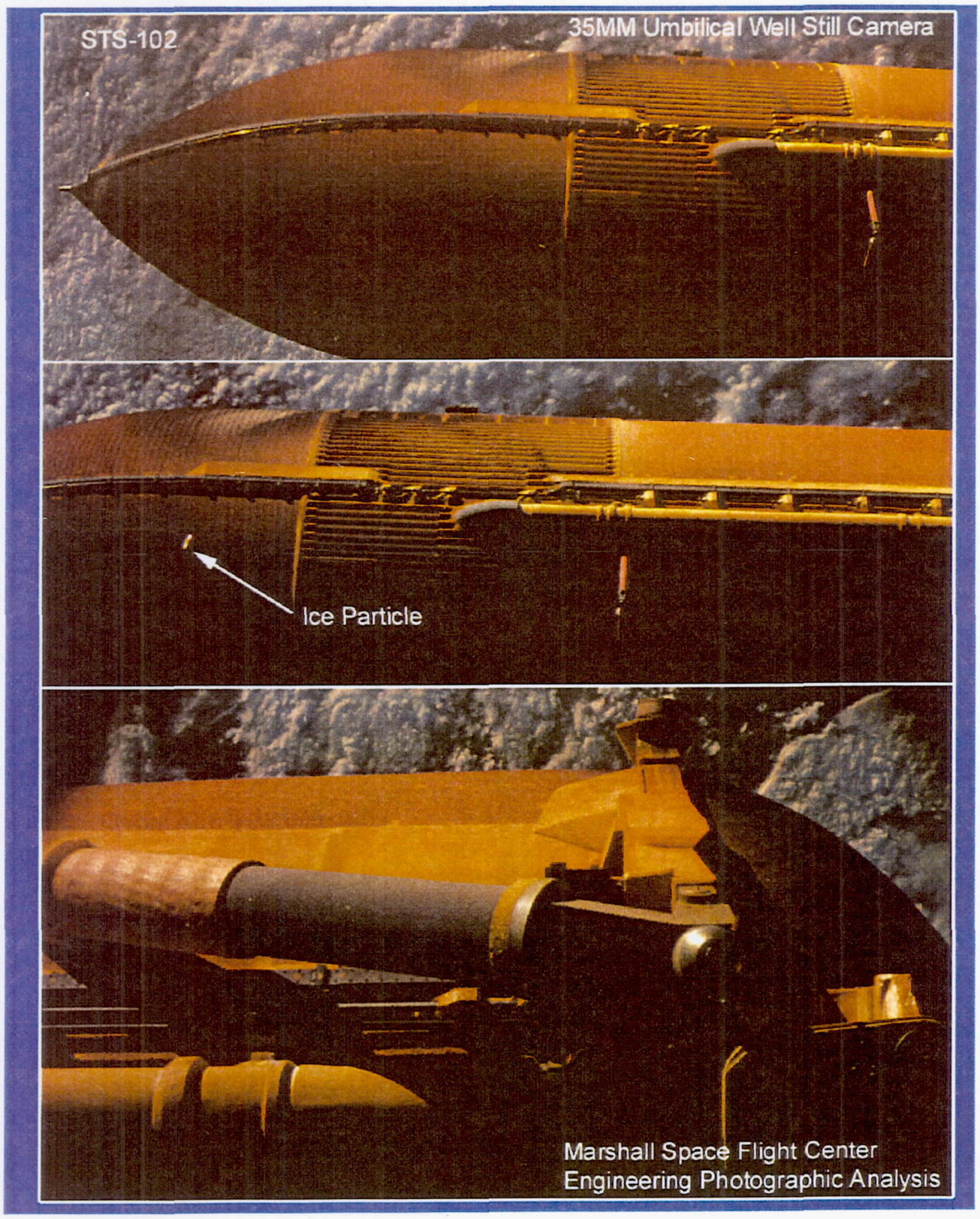


Figure 15. External Tank TPS

Umbilical Well 35mm Still Film Camera: Protruding EO-3 Interface Bolt

The EO-3 Interface Bolt was noted to be protruding from the bore of the EO-3 Interface Ball Joint. Also, the tethered red-colored purge seal was observed near the joint.

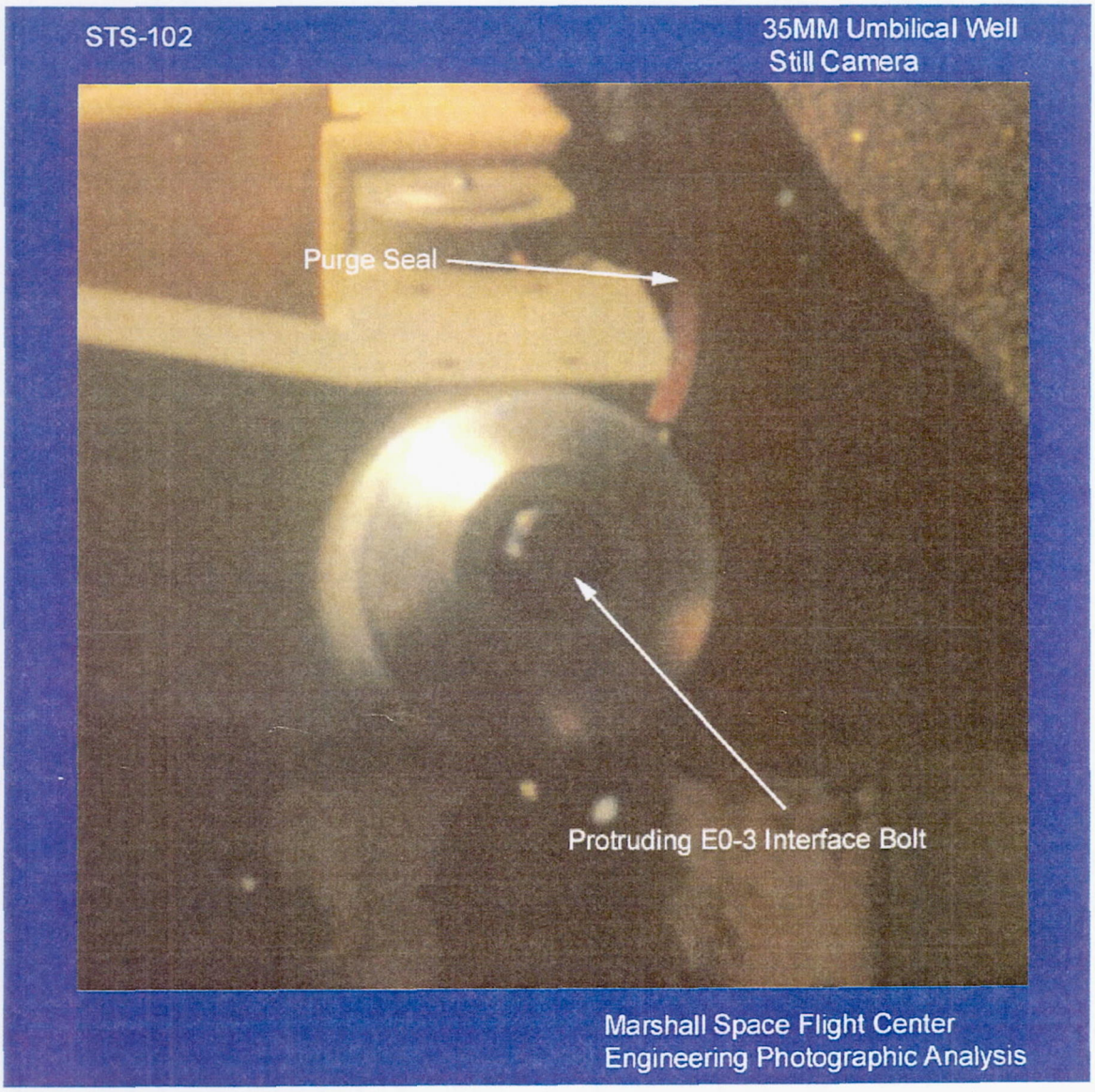


Figure 16. Protruding EO-3 Interface Bolt

Astronaut Hand Held Video Camera: External Tank +Y Thrust Panel

Typical aeroheating on the nose TPS and burn scars from the SRB separation motors on the intertank were noted on the External Tank +Y and –Y Thrust Panels.

No substantial divoting could be discerned on the ET TPS and no venting from the ET was noted on the handheld video.

Figure 17. External Tank +Y Thrust Panel

Astronaut Hand Held Video Camera: External Tank -Z Side

Typical aeroheating of the nose TPS was observed on the –Z side of the External Tank TPS.

Figure 18. External Tank -Z Side

Individual Camera Assessments:

Assessments for individual cameras are listed below. The assessments for all individual cameras including camera characteristics as noted in the Photographic Acquisition Disposition Document (PADD) for flight STS-102 may also be found on the website.

Video Camera Assessments

TV13	Glowing debris particles ejected from SRB plume after separation. SRB separation: 067:11:44:13.56 UTC.
TV4B	Pad debris noted rising and falling. Typical debris observed falling aft of vehicle. Glowing debris particles ejected from SRB plume after separation. SRB separation: 067:11:44:13.54 UTC. Frost observed on ET acreage.
TV7B	Pad debris noted rising and falling. Free burning Hydrogen observed. Frost observed on ET acreage.
ET204	Glowing debris particles ejected from SRB plume after separation. SRB separation: 067:11:44:13.5 UTC. Image focus was soft.
ET207	Typical debris observed falling aft of vehicle. Glowing debris particles ejected from SRB plume after separation. Debris-induced streaks in SSME plume. Linear optical distortions noted. Flow recirculation noted. Camera focus was soft. Typical body flap motion. Paper-like, flapping material observed at aft edge of right Stinger Pod.
ET212	Glowing debris particles ejected from SRB plume after separation. Debris ejected from SRB plume. Images were in soft focus and somewhat overexposed.
ET213	Pad debris noted rising and falling. Image focus was soft. Free burning Hydrogen observed.
TV21B	Frost observed on ET acreage. Free burning Hydrogen observed.
OTV109	Typical ice/frost from 17-inch disconnects.
OTV141	Free burning Hydrogen observed. Frost observed on ET acreage.
OTV149	Typical ice/frost from LO2 T-0 umbilical.
OTV150	Image overexposed, little engineering value.
OTV151	Free burning Hydrogen observed.
OTV154	Typical ice/frost from 17-inch disconnects. Purge barrier material debris from LH2 17 inch disconnect observed. Typical elevon motion observed.
OTV160	Pad debris noted rising and falling. Frost observed on ET acreage.
OTV161	Frost observed on LOX vent louvers.
OTV163	Typical ice/frost from 17-inch disconnects.
OTV170	Frost observed on ET acreage. Free burning Hydrogen observed.
OTV171	Typical ice/frost from LH2 T-0 umbilical. Free burning Hydrogen rises above OMS Pod.

Film Camera Assessments

E1	Pad debris noted rising and falling. Purge barrier material debris noted. Frost on ET acreage observed.
E2	Streak on SSME#1 plume observed. Free burning Hydrogen observed. Purge barrier material debris noted. Notable amount of SSME#1 drain line vapors observed.
E3	Pad debris noted rising and falling. Free burning Hydrogen observed. Notable vapors from SSME#1 drain line.
E4	Typical ice/frost from LO2 disconnect. Purge barrier material and water baggy material debris noted.
E6	Film received was E42, not E6. GUPC retraction appeared normal.
E7	Pad debris noted rising and falling. Large piece of aft skirt foam breaks free.
E8	Holddown Post M2 PIC firing time at 067:11:42:09.011 UTC. Typical pad debris observed.
E9	Holddown Post M1 PIC firing time at 067:11:42:09.012 UTC. Thread that binds adjacent thermal curtains is visible. O-Ring or washer debris item noted at 067:11:42:09.112 UTC.

E11	Holddown Post M7 PIC firing time as 067:11:42:09.011 UTC. Loose water baggy rope noted. Typical pad debris.
E12	Typical ice/frost from LH2 disconnect observed. Holddown Post M5 PIC firing time at 067:11:42:09.012 UTC. Typical pad debris.
E13	Holddown Post M6 PIC firing time at 067:11:042:09.012 UTC. Typical pad debris observed. LED segment of "4" on minutes line of timing display was burned out.
E14	Dark-colored debris item noted just after PIC firing.
E15	Frost noted on water pipes. Foam debris noted traveling forward of SRB.
E16	Typical pad debris noted.
E17	Typical ice/frost from LO2 T-0 umbilical. Free burning Hydrogen noted. Tile chips on Orbiter Base Heat Shield observed.
E18	Typical ice/frost from LH2 T-0 umbilical. Tile chips on Orbiter Base Heat Shield observed. Body flap motion observed. Plastic sheet from Tail Service Mast noted falling through field of view.
E19	Engine streak noted on SSME#1 at 067:11:42:07.094 UTC. Orbiter base heat shield chips noted. Ice on SSME#2 and SSME#1 eyelids. Free burning Hydrogen observed. SSME ignition order was 3-2-1. Mach diamond formation in 2-3-1 order. SSME#2 Mach diamond formation at 067:11:42:05.834 UTC. SSME#3 Mach diamond formation at 067:11:42:05.889 UTC. SSME#1 Mach diamond formation at 067:11:42:06.181 UTC.
E20	Ice on SSME#1 and SSME#2 eyelids. Unusually large vent plume from SSME#1 drain line. Mach diamond formation in 2-3-1 order.
E31	Typical ice/frost from LH2 disconnect. Typical wing motion at liftoff. Ice/frost noted on SSME#2 eyelid. Purge barrier material debris noted.
E33	Frost noted on GUCP and GUCA. Light brown-colored liquid streaks on LSRB observed.
E34	Typical debris observed falling aft of vehicle. Frost noted on ET acreage. Soft focus.
E36	Free burning Hydrogen noted. Soft focus.
E40	Typical debris observed falling aft of vehicle. Frost on ET acreage. Liquid streaks noted on LSRB. Ice/frost noted on SSME#2 eyelid.
E52	Frost noted along entire length of External Tank. Camera intermittently loses track of vehicle after Roll Maneuver.
E54	Pad debris noted rising and falling. Typical debris observed falling aft of vehicle. Free burning Hydrogen observed. Purge barrier material debris noted. Camera loses track of vehicle while vehicle was on pad, unable to observe all of ignition/liftoff sequence. SSME streak and associated plume brightening observed at 067:11:42:19.073 UTC.
E57	Pad debris noted rising and falling. Typical debris observed falling aft of vehicle. Water/vapor emanating from speed brake/rudder drain on vertical stabilizer observed.
E59	Frost on ET acreage. Orbiter image low in screen later in ascent.
E60	Pad debris noted rising and falling. Typical debris observed falling aft of vehicle. Typical ice/frost from 17-inch disconnects. Frost on ET acreage observed.
E62	Frost on ET acreage. Free burning Hydrogen observed. Unusually large amount of vapor from SSME#1 drain line.
E63	Frost on ET acreage noted. Free Hydrogen burning observed. Unusually large amount of SSME#1 drain line vapors.
E204	Soft focus.
E205	Glowing debris particles ejected from SRB plume prior to, during and after separation. OMS motor firing observed after separation. Soft focus.
E207	Typical debris observed falling aft of vehicle. Debris-induced streaks in SSME plume. Linear optical distortions noted. Flow recirculation noted. RCS motor firing at SRB separation observed. Glowing debris particles ejected from SRB plume during and after SRB separation. Typical body flap motion noted. RCS cover paper, not completely detached from RCS motor on Right Stinger Pod, flapping was observed. Image not in sharp focus.
E212	Glowing debris particles ejected from SRB plume prior to, during and after separation. Debris ejected from SRB plumes during ascent. RCS motor firing observed. OMS motor firing observed. Soft focus.
E213	Frost on ET acreage observed. Soft focus.

E220	Typical debris observed falling aft of vehicle. Debris-induced streaks in SSME plume. Camera loses track of vehicle.
E222	Pad debris noted rising and falling. Typical debris observed falling aft of vehicle. Frost observed on ET acreage. Camera loses track of vehicle momentarily.
E223	Pad debris noted rising and falling. Typical debris observed falling aft of vehicle. Debris-induced streaks in SSME plume. Linear optical distortions noted. OMS motor firing observed. Frost on LOX Tank observed. Film processing marks noted.
E224	Debris-induced streaks in SSME plume. Soft focus.

For further information concerning this report contact Tom Rieckhoff/TD53 at 256-544-7677 or Michael O'Farrell at 256-544-2620.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
May 2001

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-102

5. FUNDING NUMBERS
OMRSOOUO

6. AUTHOR(S)
Jorge E. Rivera

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA, John F. Kennedy Space Center
Process Engineering, Mechanical Systems Division
ET/SRB Branch, Mail Code: PH-H
Kennedy Space Center, FL 32899

8. PERFORMING ORGANIZATION REPORT NUMBER
NASA/TM-2001-210257

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

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Blanket Release

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-102. 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 scanned data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography if the launch were analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/thermal procecution system conditions and integrated photographic analysis of Space Shuttle mission STS-102 and the resulting effect on the Space Shuttle Program.

14. SUBJECT TERMS
SUBJECT CATEGORY: 15, 16
STS-102 Thermal Protection System (TPS)
Ice Debris Photographic Analysis

15. NUMBER OF PAGES

16. PRICE CODE

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

DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS REPORT DISTRIBUTION LIST 9/00

NASA - KSC

MK/J. Halsell
MK-SIO/R. Page
PH-M2/T. Hawkins
PH-H/J. D. Kelley
PH-H2/J. Rivera (7)
PH-P4-B/A. Willett
TA-B2/C. Brown
SK/F. Kienitz
USK-321/R. S. Herman
USK-708/K. Revay
721Z/K086 T. Wilson
JCI-VIPC-1/R. Robinson
MMC-15/D. S. Otto
USK-840/L. Clark

NASA - JSC

Johnson Space Center
Houston, Texas 77058

EP4/P. Cota
ES/G. Galbreath
MV/K. Brown
MV/J. Mulholland
SN3/E. Christiansen
SN3/G. Byrne

NASA - MSFC

Marshall Space Flight Center
Huntsville, AL 35812

EE31/J. L. Lusaka
TD53/T. J. Rieckhoff
MP51/J. Sambamurthi
841-ZA12/J. Hixson

Rockwell - Downey

The Boeing Company
5301 Bolsa Ave.
Huntington Beach, CA 92647

H019-F701 /J. McClymonds
H017-D416 /R. Ramon

Lockheed Martin

LockheedMartin Michoud Assembly Facility
13800 Old Gentilly Road
New Orleans, Louisiana 70129

Dept. 4610/P. A. Kopfinger
MAF Technical Library