6.0 FILM REVIEW

Anomalies observed in the Film Review were reported 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.

6.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 84 films and videos, which included twenty-eight 16mm films, eighteen 35mm films, and thirty-eight videos, were reviewed starting on launch day.

Frost, but no ice, formed on the ET louvers after GOX vent seal retraction (OTV 060).

SSME ignition appeared normal with Mach diamonds forming in the expected 3-2-1 sequence. Two streaks occurred in the SSME exhaust plume from early liftoff through tower clear (E-2, -3, -19, -20, -52, -76, -77; OTV 051, 070, 071).

Free burning hydrogen was visible in the orbiter base heat shield area, near the drag chute door, vertical stabilizer root, and under the body flap during SSME ignition (OTV 063, 070, 071, TV-7).

SSME ignition caused numerous pieces of ice from the LH2 ET/ORB umbilical to fall aft. Some pieces impacted the umbilical cavity sill, but no tile damage was visible. In addition, a piece of 1-inch wide mylar tape came loose from the forward portion of the ET/ORB LH2 umbilical purge barrier and fell aft (OTV 009, 054).

Small pieces of tile surface coating material were lost during ignition from several places on the base heat shield outboard of SSME #3 and SSME #2, on the +Y APCS pod aft surface, and on the body flap +Z side outboard of SSME #3 (OTV 070; E-17, -18, -19, -20).

Retraction of the LO2 Orbiter T-0 carrier plate caused pieces of ice to shake loose and fall aft impacting the SSME #3 nozzle near the #8 hatband. No damage occurred (OTV 070).

Although not an anomaly but just an unusual occurrence, a total of seven aft RCS thruster paper covers were still intact after T-0 as the vehicle lifted off. The covers normally are torn by SSME ignition vibration and acoustics early in the start-up process (OTV 049, 050).

Several pieces of ice/frost that had formed on the +Y longeron during tanking as a result of the cracks in the closeout TPS fell aft and impacted the +Y vertical strut. These impacts did not cause any damage (OTV 054).

GUCP disconnect from the ET was normal. There was no TPS damage (E-33).

No holddown post stud hang-ups occurred on this launch. No debris fell from the DCS stud holes (E7-14). IFA STS-101-1-01 was taken for unusual high frequency responses in the strain gage data on holddown posts M-2 and M-4. However, film review showed no unusual vehicle or GSE movements/anomalies in these areas.

The GN2 purge lines separated cleanly from both SRB aft skirts at liftoff. The purge lines were visible for about two seconds after T-0. No anomalies were observed (E-8, -13).

Several pieces of SRB throat plug were ejected from the flame trench after T-0 in northern trajectories away from the SSV (TV-7). A long, thin, dark debris object, most likely a piece of SRB throat plug or sound suppression water trough material, crossed the field of view moving northward away from the vehicle at 11:11.623 GMT (E-1, -41).

TV-21 showed an object believed to be a cable tray cover from the FSS or a PCR panel from the RSS moving westward away from the SSV shortly after T-0. The object appeared to originate from the 135 or 155 foot level of those structures.

All views showing the +Y longeron containing the cracked TPS detected prior to launch confirmed no foam loss while in the field of view. The 2-inch diameter ice/frost formation was still attached to the +Y longeron at the start of the roll maneuver (E-52, -54).

Condensate drained from the split rudder/speed brake shortly after liftoff (E-52).

TV-4A recorded pieces of forward RCS thruster paper covers falling aft of the vehicle at 16.5 and 27 seconds MET. A large flare occurred in the SSME #1 exhaust plume at 53 seconds MET for 0.17 seconds duration in this field of view. This type of flare is usually caused by debris, such as a particle of SRB aft skirt aft ring instafoam, passing through the exhaust plume. The large flare in the SSME #1 exhaust plume at 10:12:03.279 GMT was also visible in E-207 frame 2804, E-220 frame 5803, E-222, -223, and -224.

At least two more pieces of instafoam fell aft at 64 and 74 seconds MET.

A circumferential ring, somewhat brighter than the adjacent hot wall nozzle material but not an anomaly, was visible in SSME #2 (E-207).

Frequency and amplitude of body flap motion appeared to be typical. The view from film item E-207 was especially good.

SRB tail-off and separation appeared normal. Numerous pieces of slag falling out of the exhaust plume during and after SRB separation was typical (TV-4, TV-13).

OMS engine ignition was easily visible in film items E-208 and 212.

6.1.1 Vaporous Streak at 34 Seconds MET

An impact occurred at 10:11:44.109 GMT (approx. T+34 seconds MET) on the Orbiter lower surface at a point that appeared to be about 8 feet forward of the right inboard elevon hinge, perhaps centered with respect to the elevon or just a little more outboard (E-224).

This event in turn caused a light-colored, "vaporous" streak to pass the trailing edge of the right inboard elevon at T+34 seconds MET.

The debris object was white, or light-colored, perhaps 6 inches in length, and disintegrated upon impact thereby comprising most of the material in the "streak", though there may also have been some tile material as well from the damage site.

After the impact, no damage site could be discerned. However, the film was grainy and individual tiles could be resolved. Therefore, the damage site was not extremely large, which would have been visible to some degree.

The debris object appeared to originate from the mid-body area of the vehicle, though that could not be precisely determined due to the grainy nature of the image as well as that portion of the vehicle being in deep shadow.

Since the debris object disintegrated upon impact with no large particles visible in the "streak", the object most likely was a piece of ET foam or crusty ice from the ET LO2 feedline bellows or support brackets. It is unlikely the object was a piece of SRB insulation since no significant material was found to be missing during the post flight inspection at Hangar AF. Likewise, the object could not be a white tile since the trajectory would take it aft over the wing with no mechanism to carry a white tile along the lower surface.

A second, very nebulous streak occurred approximately 7 second later (11:51.5 GMT). That may indicate either another piece of foam or ice came loose and followed the same trajectory, or the tile damage site continued to erode.

This streak was compared to a somewhat similar streak detected on STS-26R, which was the result of a debris impact that caused a tile damage site 18 inches long by 8 inches wide by 1.5 inches deep. However, the STS-101 streak was considerably less "dense" indicating a much smaller damage site.

Shuttle Program management elected not to use the RMS for a tile survey due to lighting problems and poor resolution on such previous surveys. However, it was prudent to take some precautions anyway, so the Orbiter performed a thermal conditioning maneuver prior to re-entry to cold bias the right wing and elevon structure. This increased the temperature margin and, therefore, reduced the potential for structural damage. The detection of the debris impact and resulting damage site was not considered a Safety of Flight issue, but more of an R&R effort after landing.

6.2 SRB CAMERA VIDEO SUMMARY

Both cameras provided good views. Lighting and focus were excellent. The fields of view on this flight were compared to STS-103. The +Y side of STS-101 was identical to STS-103. The –Y side was shifted 1.5 inches in the +Z direction and 4 inches in the –X direction, which was an insignificant change.

As expected, divots were smaller in size and fewer in number in the vented areas of the thrust panels when compared to the unvented areas. Some very small areas of exposed "new" foam were caused by normal ascent recession/erosion and not included in the total divot count. Divots were very shallow with no primed substrate visible. Most divots were small and less than 0.5 inches in diameter.

There was a greater number of divots visible in the right field of view (+Y side) compared to the left (-Y) side.

The right SRB camera viewing the +Y side of the ET recorded a light colored spot appearing at 90 seconds MET on the Orbiter lower surface that may be a tile damage site. However, no debris object was observed impacting this area.

A divot approximately 9-inches in diameter was present on the ET –Z side at the intertank-to-LH2 tank interface.

6.2.1 -Y Side Divot Count

100 seconds MET	One small divot appeared in vented rib #18 just aft of Xt-963
100-110 sec MET	10 total divots on ribs (none greater than 1-inch in size)
110-120 sec MET	38 total divots (with 1 greater than 1-inch in size on rib #23)
120-124 sec MET	58 total divots (no additional divots greater than 1-inch)
After separation	3-inch divot at rib #15 adjacent to LH2 acreage flange closeout

6.2.2 +Y Side Divot Count

99 seconds MET	First divot appeared on the circumferential rib ramp at Xt-963 between ribs #5 and #6
99-109 sec MET	23 divots in the vented area (zero greater than 1-inch in size) 14 divots in unvented area aft of station Xt-1013 (with four greater than 1-inch)
109-119 sec MET	78 divots in the vented area (one greater than 1-inch rib #7) 50 divots in unvented area aft of station Xt-1013 (with 16 greater than 1-inch aft of Xt-1013 at ribs #2, #3, and #4)
119-124 sec MET	92 divots in the vented area (one greater than 1-inch rib #7) 78 divots in unvented area aft of station Xt-1013 (with 21 greater than 1-inch aft of Xt-1013 at ribs #2, #3, and #4)
After separation	Numerous large divots visible in the unvented area aft of Station Xt-1013 with the largest estimated 3-4 inches long 6 divots were noted in adjacent valley ramps of ribs #1-7 at circumferential rib station Xt-1058

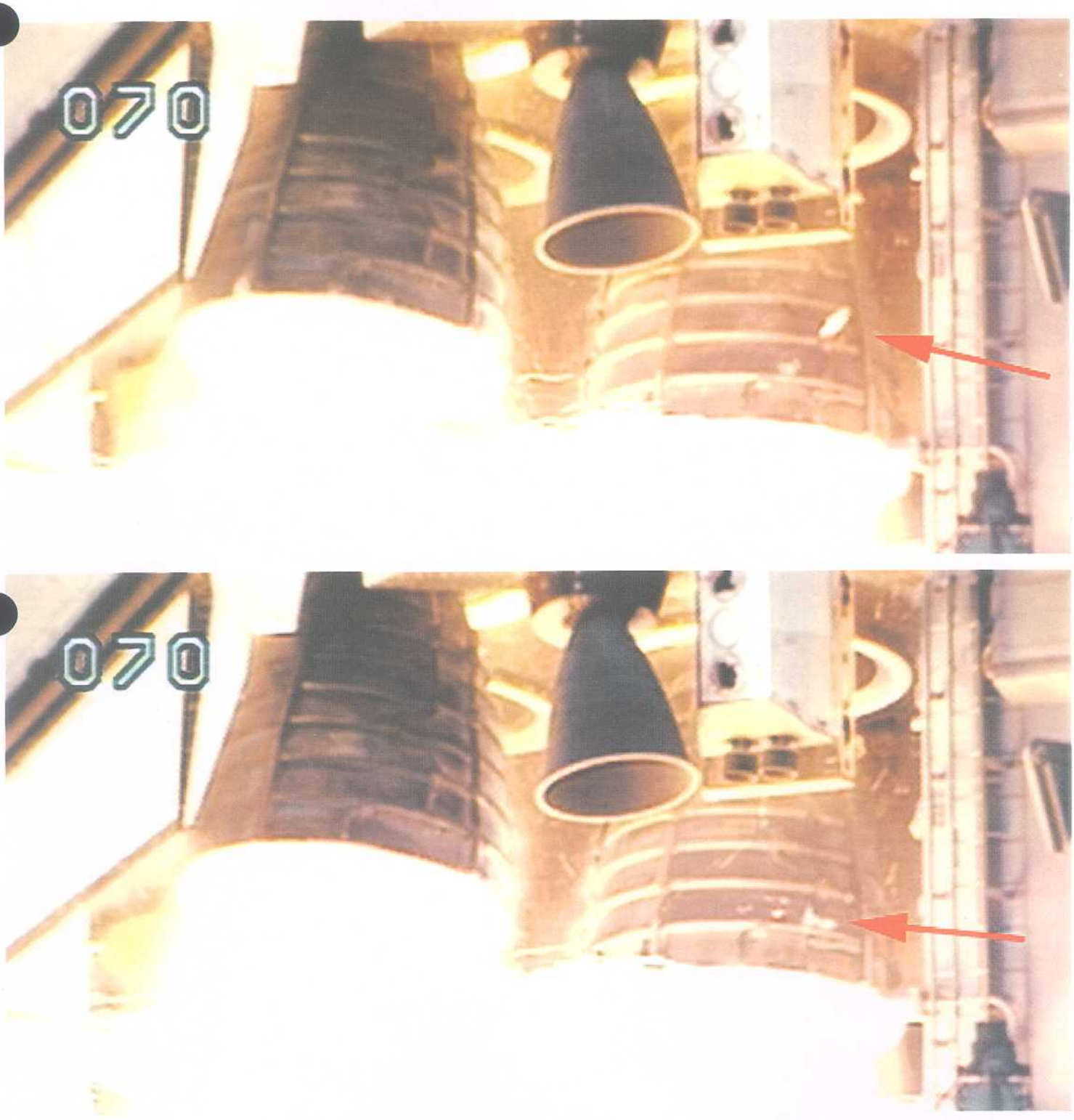

Photo 13: Ice Contacting SSME #3 Nozzle

Retraction of the LO2 Orbiter T-0 carrier plate caused pieces of ice to shake loose and fall aft impacting the SSME #3 nozzle near the #8 hatband. No damage occurred.

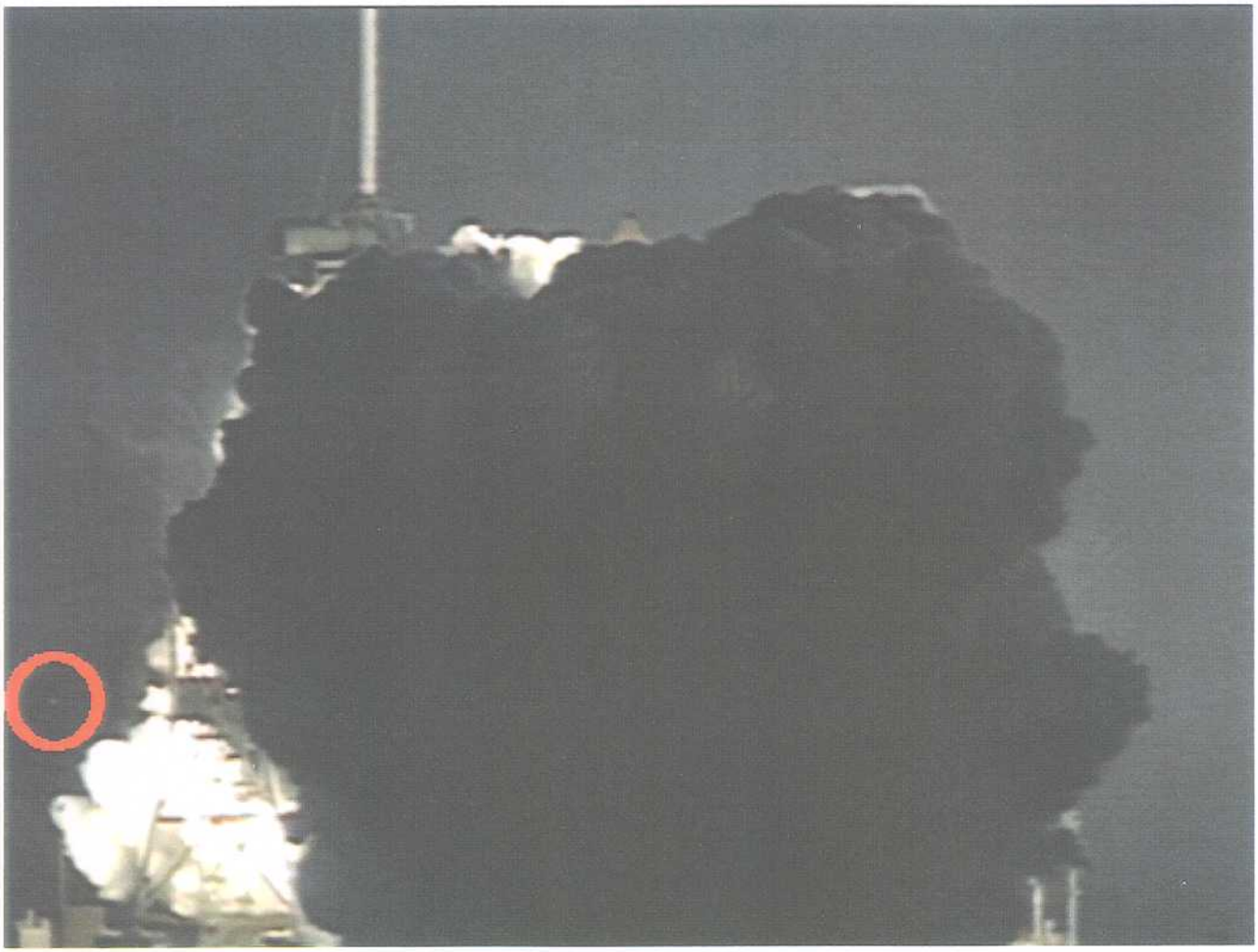

Photo 14: Debris from RSS/FSS

TV-21 showed an object believed to be a cable tray cover from the FSS or a PCR panel from the RSS moving westward away from the SSV shortly after T-0. The object appeared to originate from the 135 or 155 foot level of those structures.

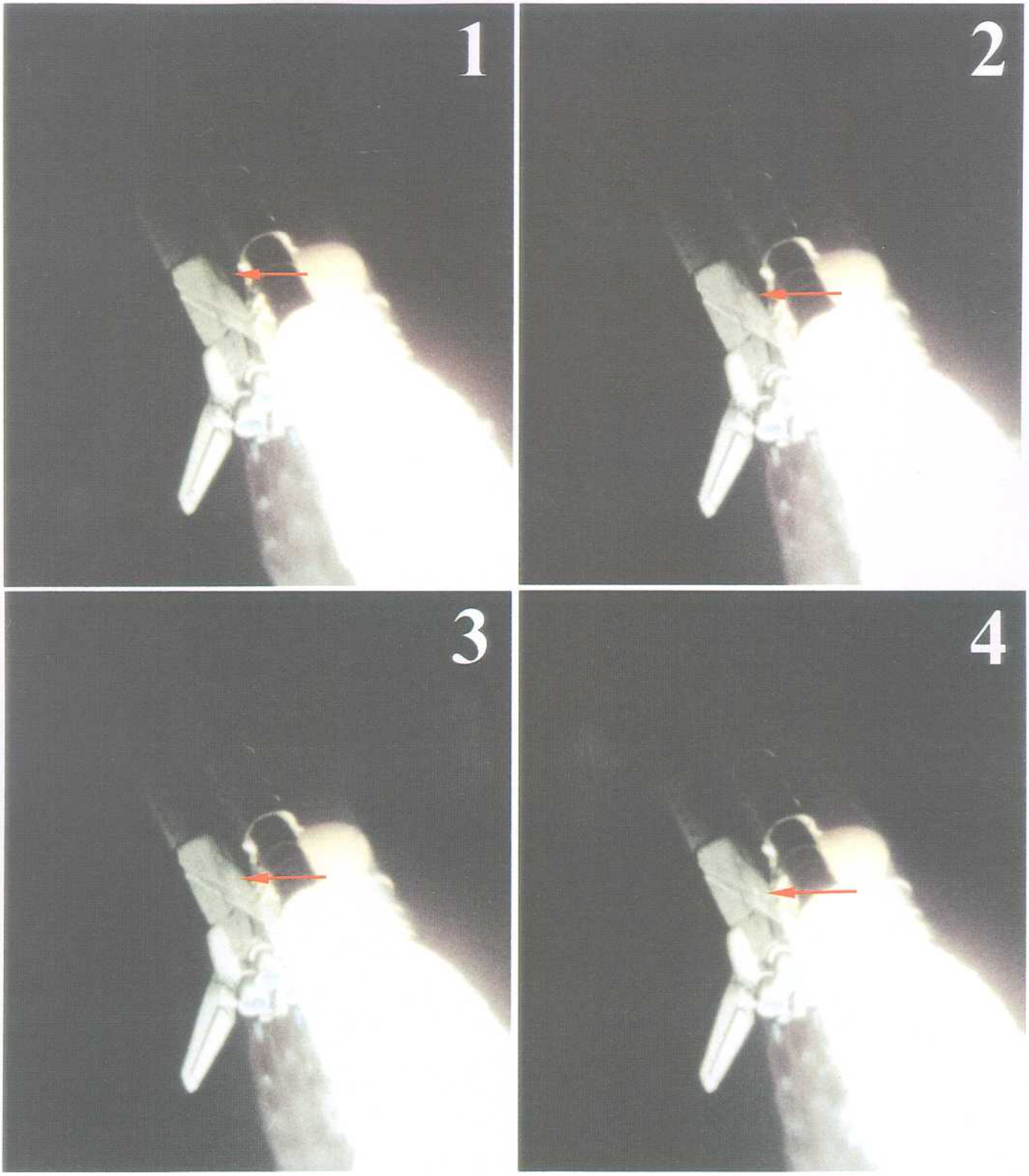

Photo 15: Ice Impacting Orbiter Right Wing

A debris object, believed to be a piece of ice from the ET LO2 feedline upper bellows, impacted the Orbiter lower surface at 10:11:44.109 GMT (T+34 seconds MET). The ice passed the main landing gear door area (1), continued a trajectory aft (2), impacted and disintegrated at a point that appeared to be about 8 feet forward of the right inboard elevon hinge (3), and created a cloud of ice particles/tile material (4).

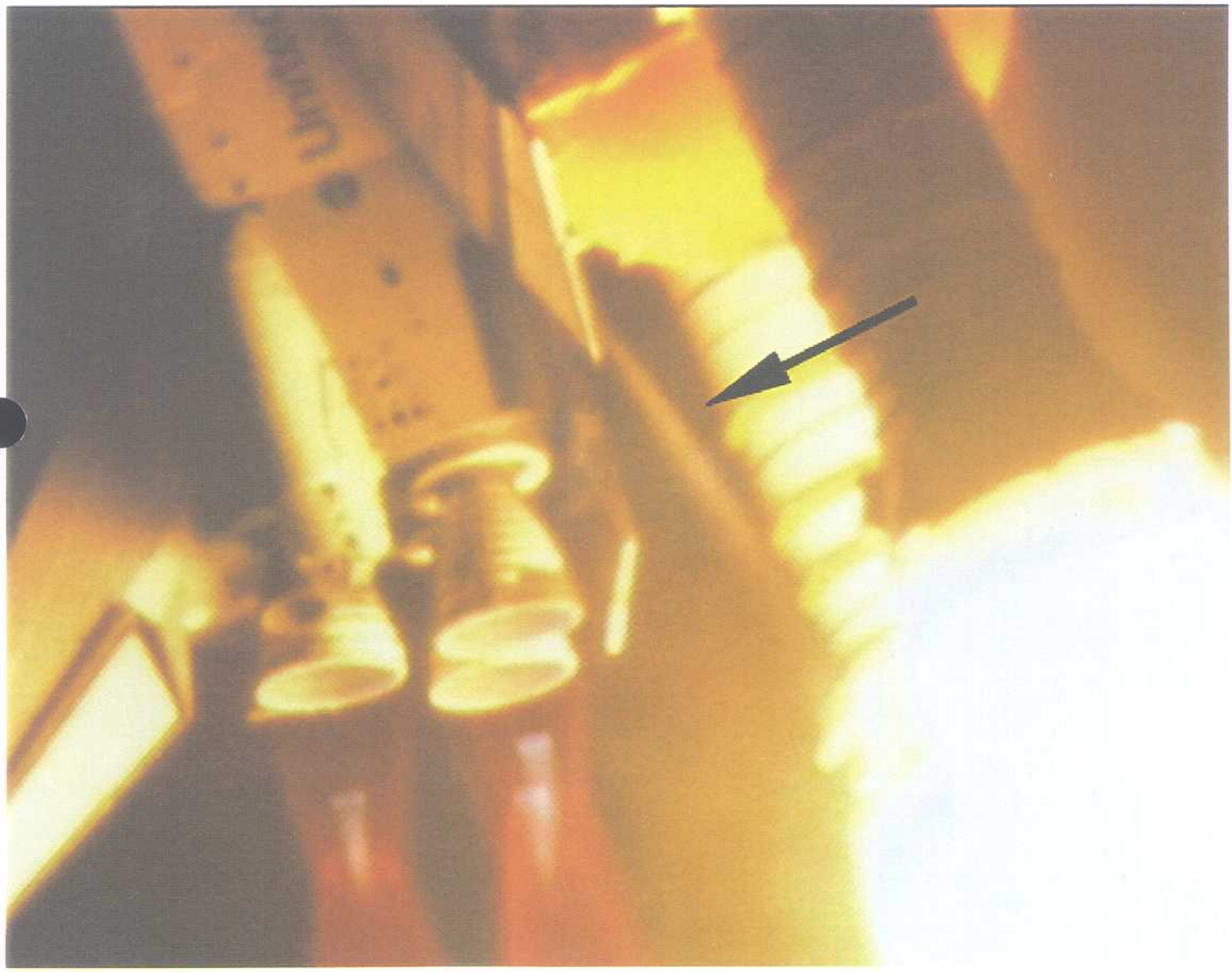

Photo 16: Vaporous Streak from Right Wing

The ice impact caused a light-colored, "vaporous" streak to pass the trailing edge of the right inboard elevon. The ice, perhaps 6 inches in length originally, disintegrated upon impact thereby comprising most of the material in the "streak", though there may also have been some tile material as well from the damage site.

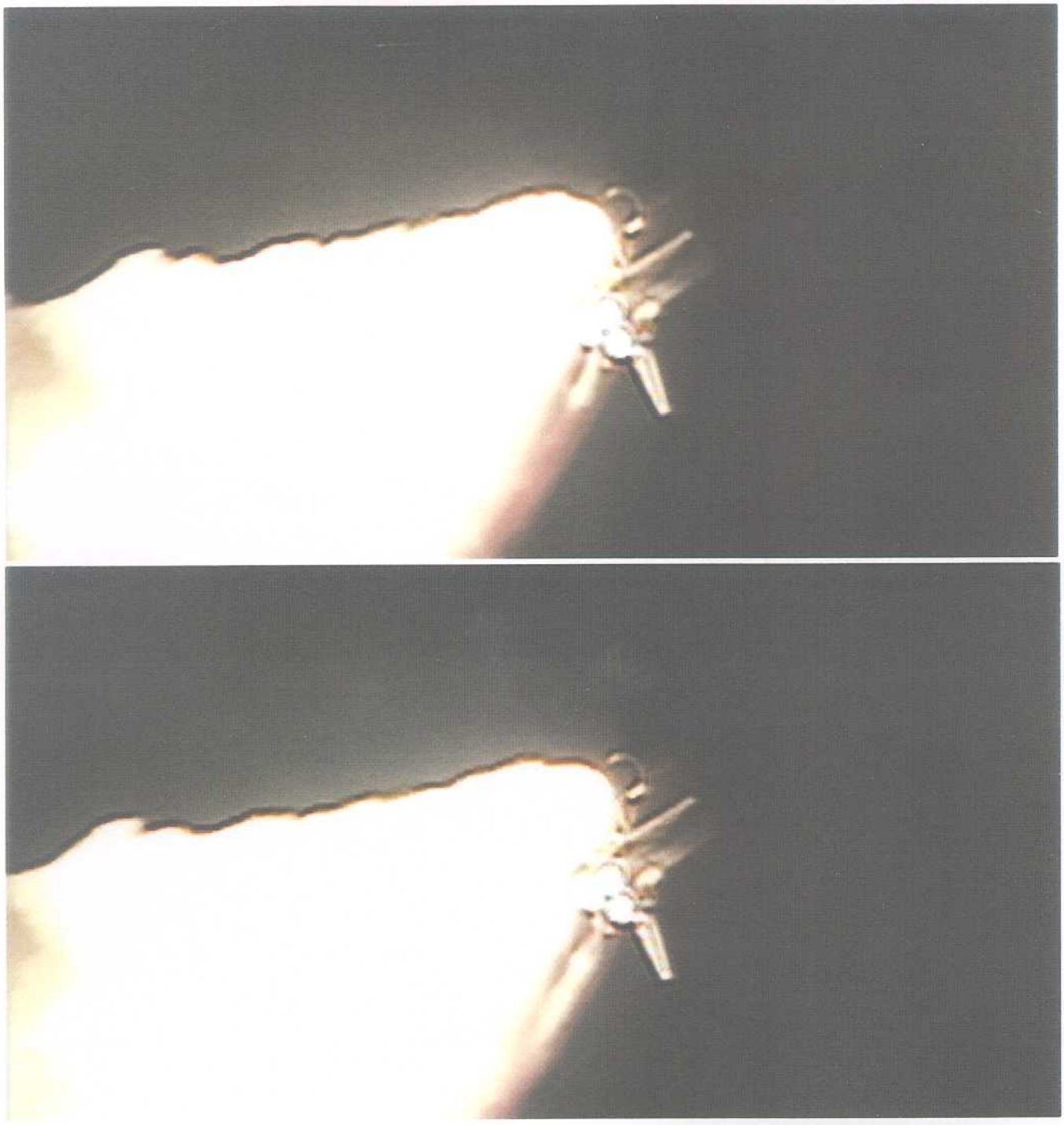

Photo 17: Large Flash in SSME Plume

A large flare occurred in the SSME #1 exhaust plume at 53 seconds MET for 0.17 seconds duration. This type of flare is usually caused by debris, such as a particle of SRB aft skirt aft ring instafoam, passing through the exhaust plume.

6.3 ON-ORBIT FILM AND VIDEO SUMMARY

6.3.1 16mm Film Footage

OV-104 was equipped to carry ET/ORB umbilical cameras: 16mm motion picture with 5mm lens and 16mm motion picture with 10mm lens from the LH2 side; 35mm still views from the LO2 side. The 16mm camera with the 5mm lens did not run.

The 16mm film from the camera with 10mm lens was predominantly dark due to time of launch (for SRB coverage) and sun angle/silhouette (during ET separation). So not much detail was discernible.

Most of the left SRB was not in the field of view. The part that was visible indicated a nominal separation.

During ET separation, no damage was noted on the LH2 ET/ORB umbilical with one exception. The forward outboard portion (10 o'clock position) of the purge seal had pulled loose and protruded in the +Z direction.

A debris object passed close to the camera lens in a fore to aft direction as the distance between separated ET and Orbiter increased (frame 7830). Since the object was silhouetted, no detail such as color or surface finish could be discerned. However, due to the large inner diameter, the object was believed to be an O-ring of some type rather than a washer. The origin was not determined.

6.3.2 35mm Film Footage

The 35mm still images from the LO2 ET/ORB umbilical camera of the External Tank after separation from the Orbiter 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. Consequently, the presence of divots in the LH2 tank-to-intertank flange closeout between the bipods and near the –Y thrust panel could not be confirmed in this film. Also, due to the timing of the +X translation, the film ended before the LO2 tank and nose cone came into view.

No anomalies or missing TPS were detected on the pressurization line ice/frost ramp at XT-1657, which had been repaired the day before launch (reference PR ET-102-TS-0016). The ramp TPS had been damaged by a falling pip pin during platform operations on the launch pad.

A white object, which appeared to be an ice/frost formation approximately 3 inches in diameter, adhered to the +Y longeron TPS closeout in the area where a vertical crack was detected during cryoloading prior to launch. The object protruded far enough to cast a noticeable shadow and may have been a lifted piece of the closeout foam itself, but more likely was condensate/water vapor inside the crack venting at altitude as the atmospheric pressure decreased. Ascent aeroheating probably had decreased enough to permit this moisture to freeze in place.

A divot in the forward surface outboard edge of the +Y vertical strut cable tray closeout was estimated to be 4 inches long by 2 inches wide.

Seven small divots, possibly caused by ice debris impacts, were noted in the +Y thrust strut TPS near the flange/knuckle.

ET LH2 tank and intertank acreage appeared nominal.

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

6.3.3 Crew Hand-Held Still Images

The flight crew obtained 35 images of the External Tank after separation using the hand held Nikon camera. In all of the views, the External Tank was well illuminated by sunlight. Focus was good. However, the ET was somewhat distant (2300 meters) making the detection of small features more difficult. Only the –Z side of the ET was not imaged.

No anomalies were detected on the nose cone. TPS immediately aft of the nose cone was eroded, but the presence of small divots could not be discerned.

A light spot in the LH2 tank-to-intertank flange closeout on centerline between the bipods and a light spot in the LH2 tank-to-intertank flange closeout near the –Y thrust panel may be divots, but could not be confirmed in the other films.

Likewise, a light spot on the –Y thrust strut to longeron interface (knuckle) TPS closeout may be a divot.

Numerous frames showed a light spot on the –Z edge of the +Y longeron TPS closeout mid way between the thrust strut knuckle and the vertical strut that may be a divot.

In other observations, no anomalies were detected on the composite nose cone. Loss of topcoat and erosion of foam in the forward ogive sanded area was visible, but the presence of divots could not be confirmed.

Both +Y and –Y intertank thrust panels, including areas not visible in the two SRB video cameras, exhibited no large divots (5-inches in diameter or greater). Smaller divots could not be discerned due to the subject distance and resolution.

No anomalies were detected in the LO2 and LH2 tank acreage. As expected, the aft dome TPS was darkened by charring, which did not quite reached the XT-2058 ring frame.

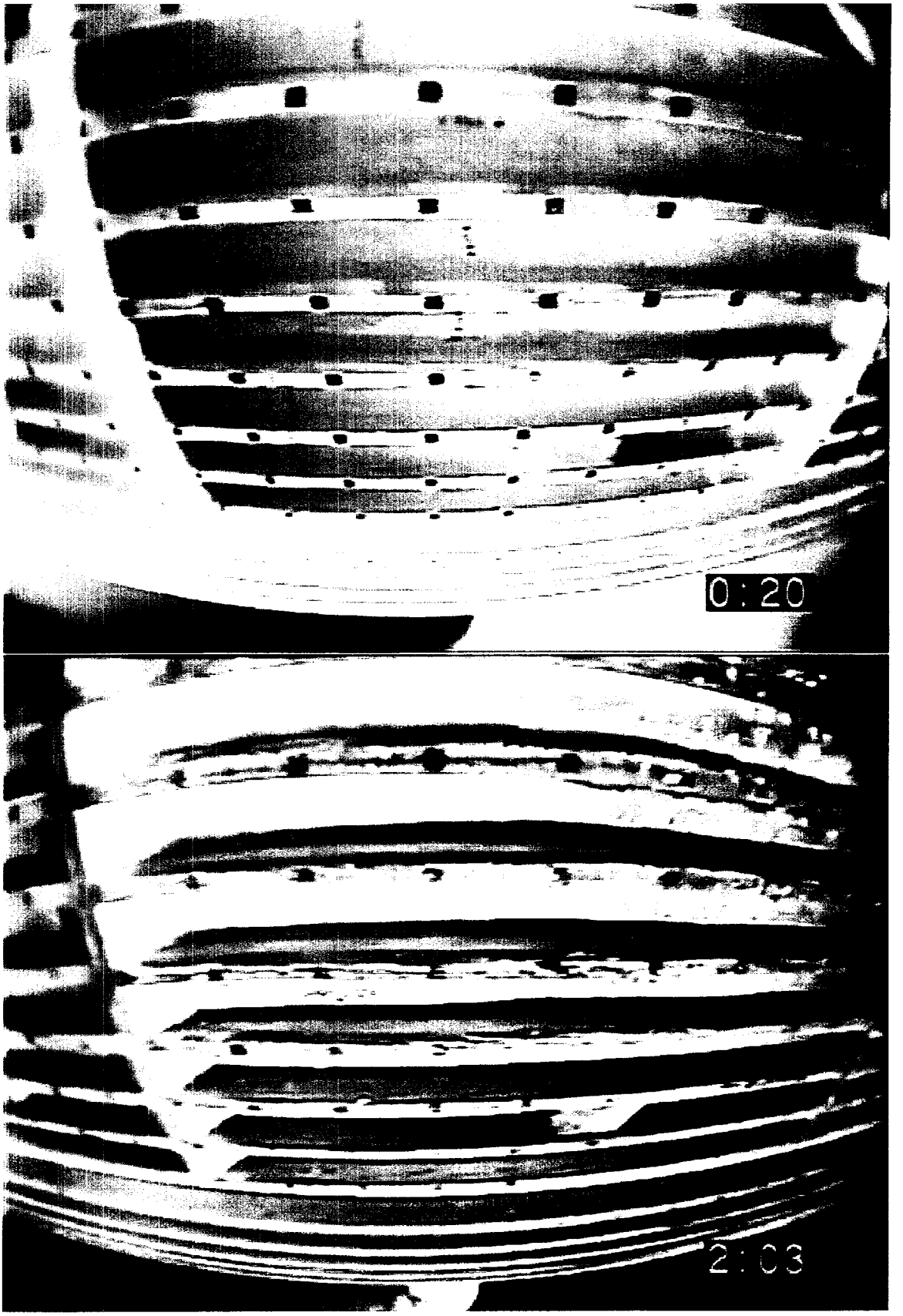

Photo 18: ET -Y Thrust Panel

Views of the ET –Y thrust panel at 20 and 123 seconds MET. As expected, divots were smaller in size and fewer in number in the vented areas when compared to the unvented areas. Some very small areas of exposed "new" foam were caused by normal ascent recession/erosion and not included in the total divot count. Divots were very shallow with no primed substrate visible. Most divots were small and less than 0.5 inches in diameter.

Photo 18: ET -Y Thrust Panel

Views of the ET –Y thrust panel at 20 and 123 seconds MET. As expected, divots were smaller in size and fewer in number in the vented areas when compared to the unvented areas. Some very small areas of exposed "new" foam were caused by normal ascent recession/erosion and not included in the total divot count. Divots were very shallow with no primed substrate visible. Most divots were small and less than 0.5 inches in diameter.

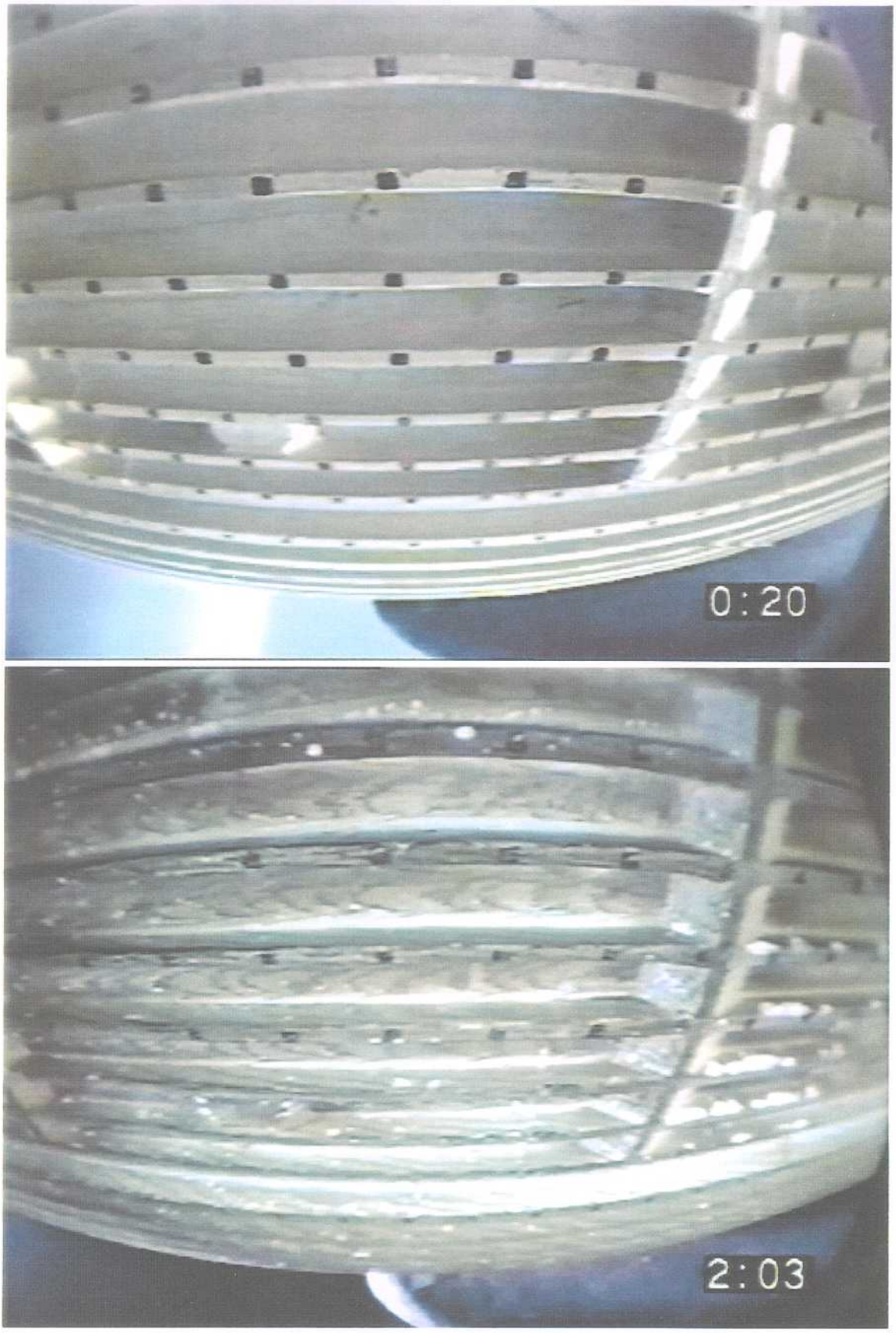

Photo 19: ET +Y Thrust Panel

Views of the ET +Y thrust panel at 20 and 123 seconds MET. As expected, divots were smaller in size and fewer in number in the vented areas when compared to the unvented areas (note larger divots in the right side of the frame). Generally, divots in vented areas were less than 0.5 inches in diameter and shallow in depth.

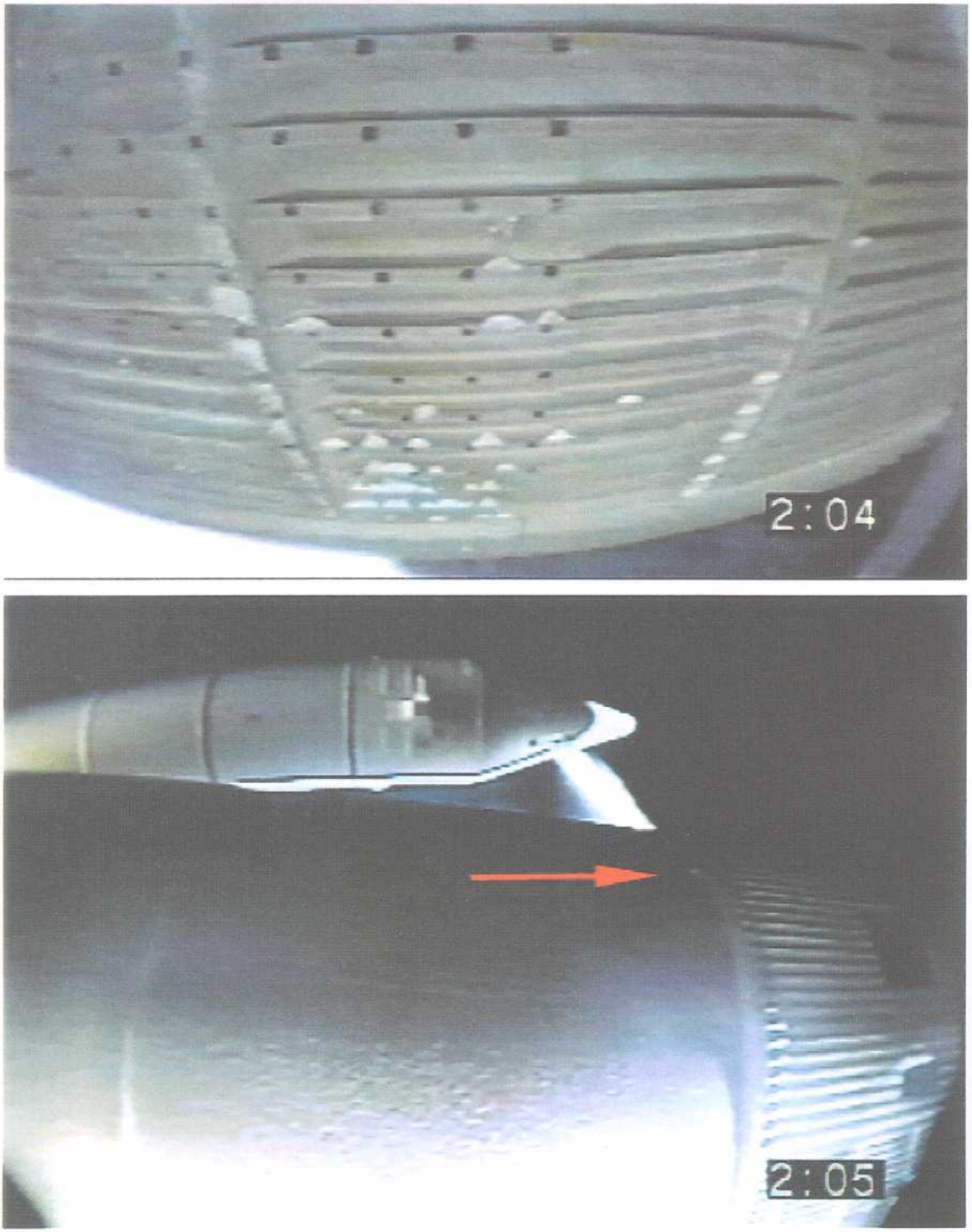

Photo 20: Divot on -Z Side

At the start of SRB separation from the External Tank, the camera had a more direct view of the larger divots located in intertank stringers where the TPS was not vented. Bottom photo shows a divot approximately 9-inches in diameter on the ET –Z side acreage just aft of the intertank-to-LH2 tank splice.

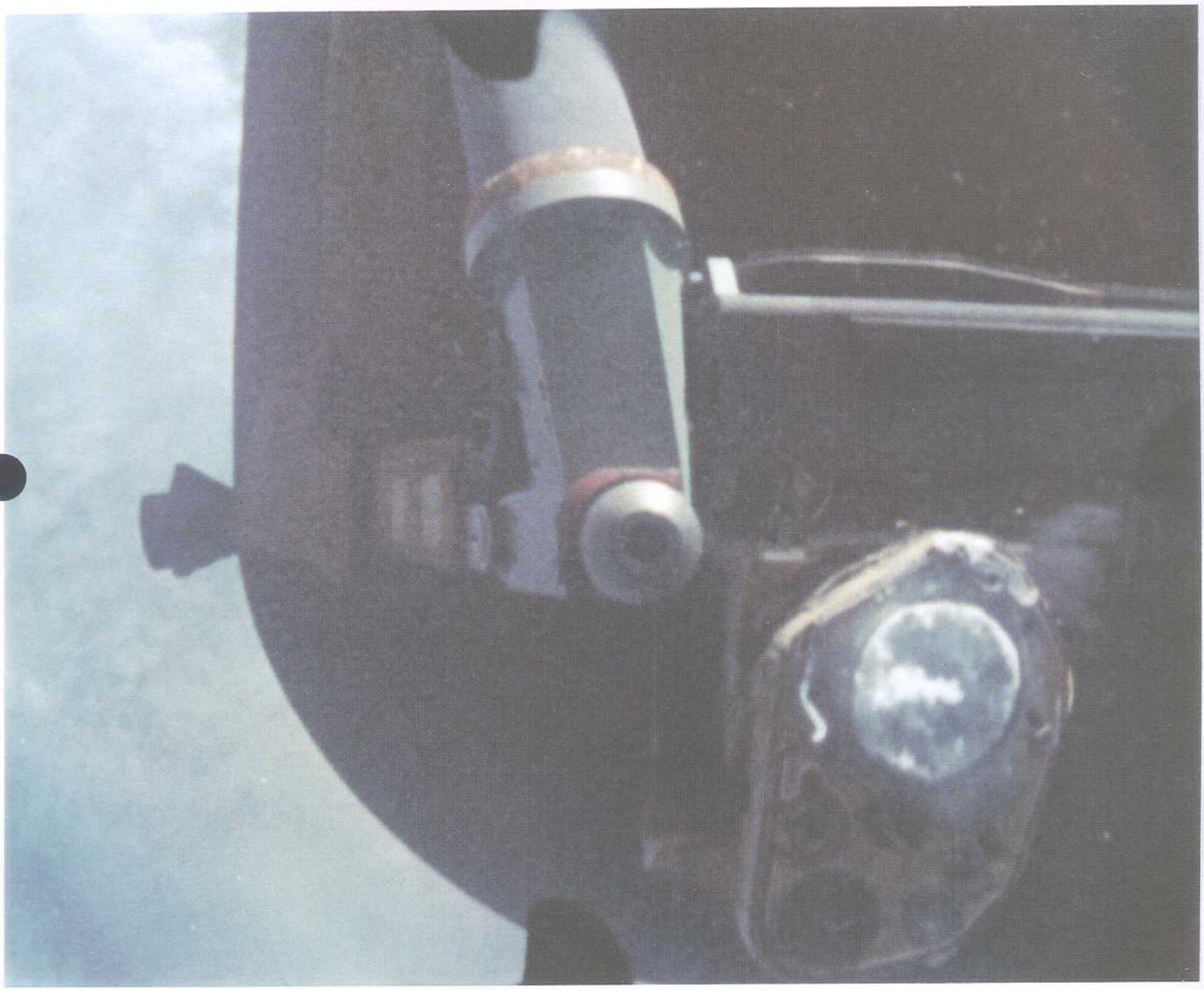

Photo 21: Protruding Purge Seal

During ET separation, no damage was noted on the LH2 ET/ORB umbilical with one exception. The forward outboard portion (10 o'clock position) of the purge seal had pulled loose and protruded in the +Z direction.

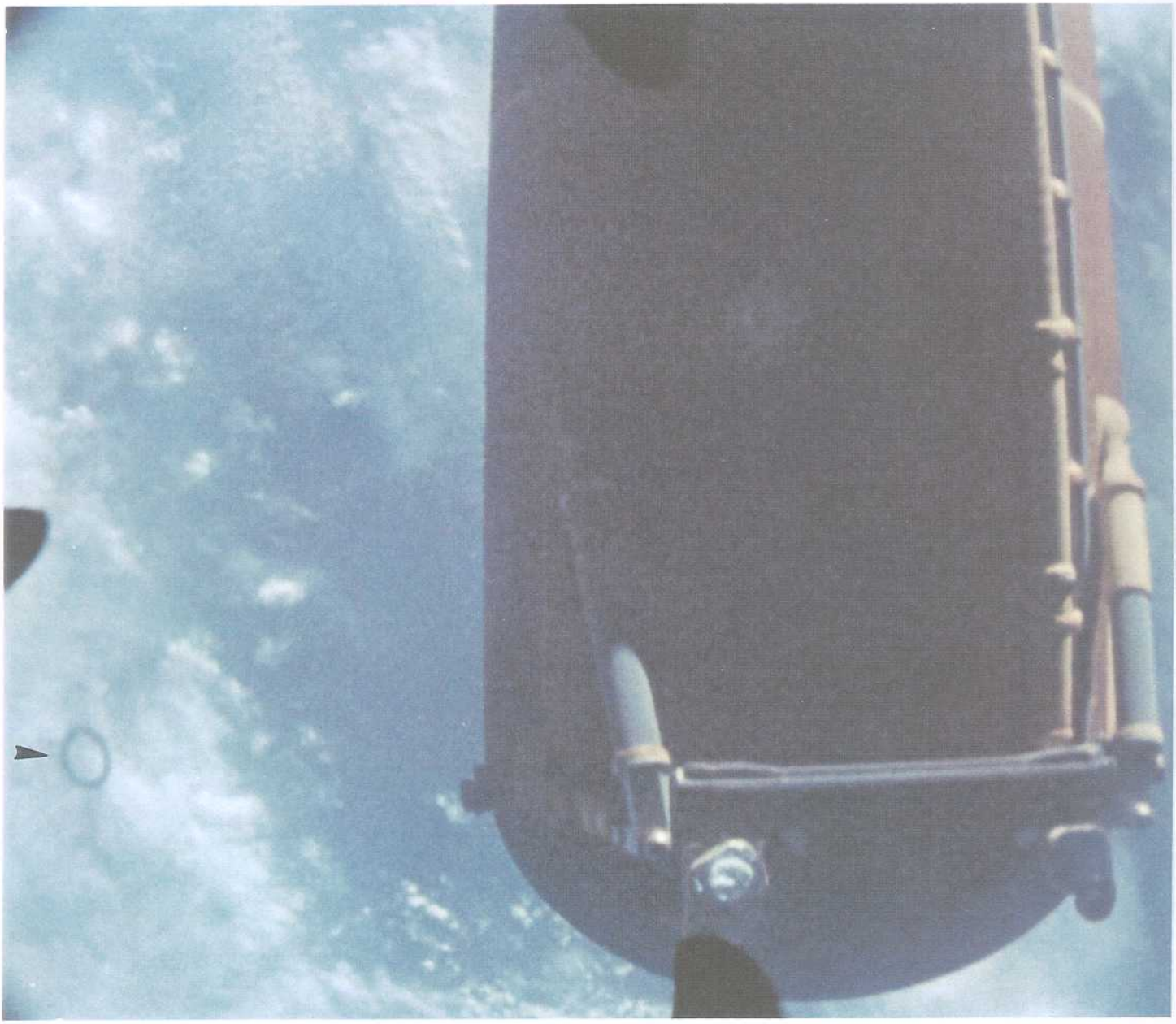

Photo 22: Loose O-Ring

A debris object passed close to the camera lens in a fore to aft direction as the distance between separated ET and Orbiter increased. Since the object was silhouetted, no detail such as color or surface finish could be discerned. However, due to the large inner diameter, the object was believed to be an O-ring of some type rather than a washer. The origin was not determined.

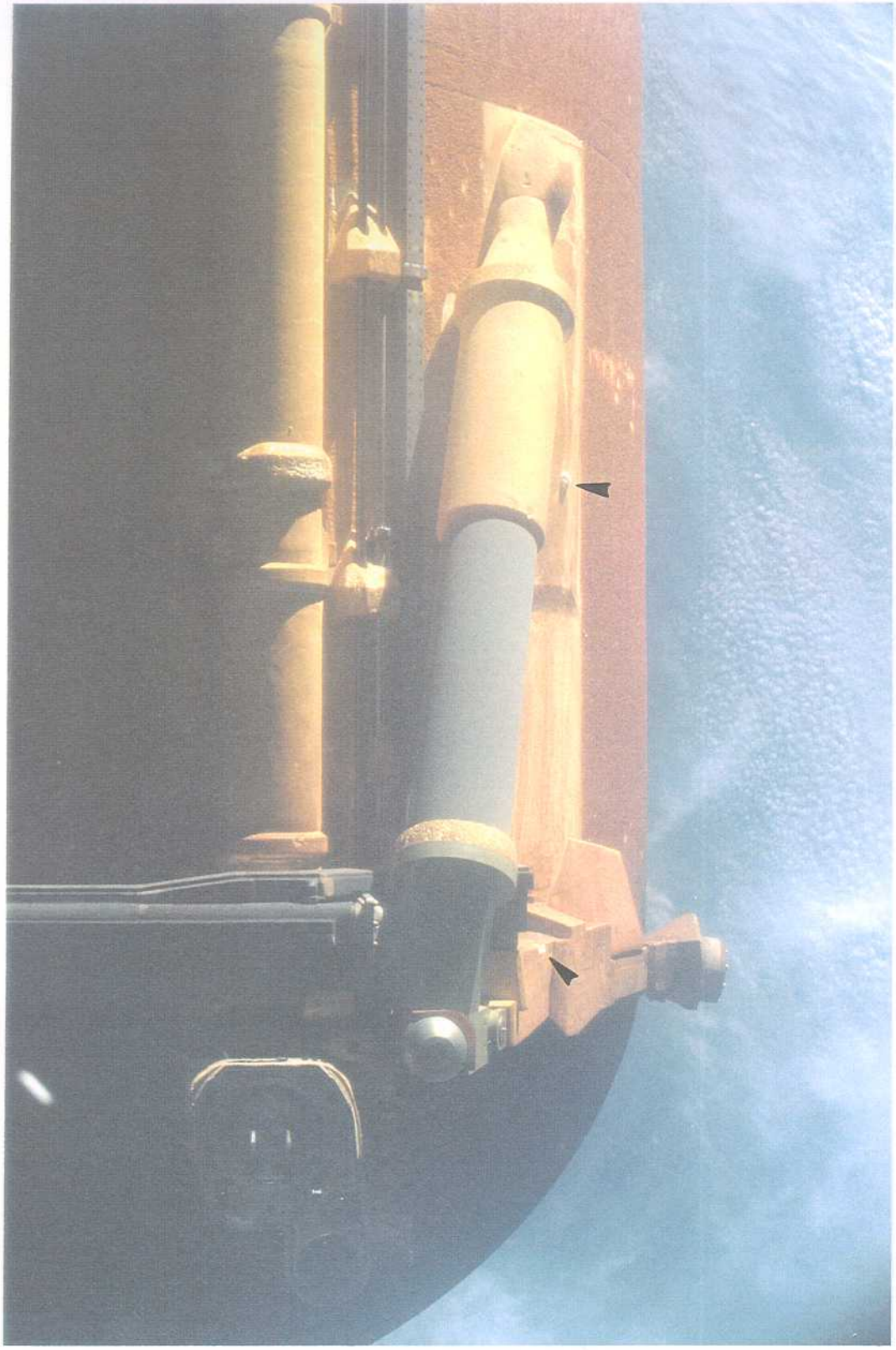

Photo 23: ET After Separation

A white object, which appeared to be an ice/frost formation approximately 3 inches in diameter, adhered to the +Y longeron TPS closeout in the area where a vertical crack was detected during cryoloading prior to launch (arrow). The object protruded far enough to cast a noticeable shadow and may have been a lifted piece of the closeout foam itself, but more likely was condensate/water vapor inside the crack venting at altitude as the atmospheric pressure decreased. Ascent aeroheating probably had decreased enough to permit this moisture to freeze in place. A divot in the forward surface outboard edge of the +Y vertical strut cable tray closeout was estimated to be 4 inches long by 2 inches wide (arrow).

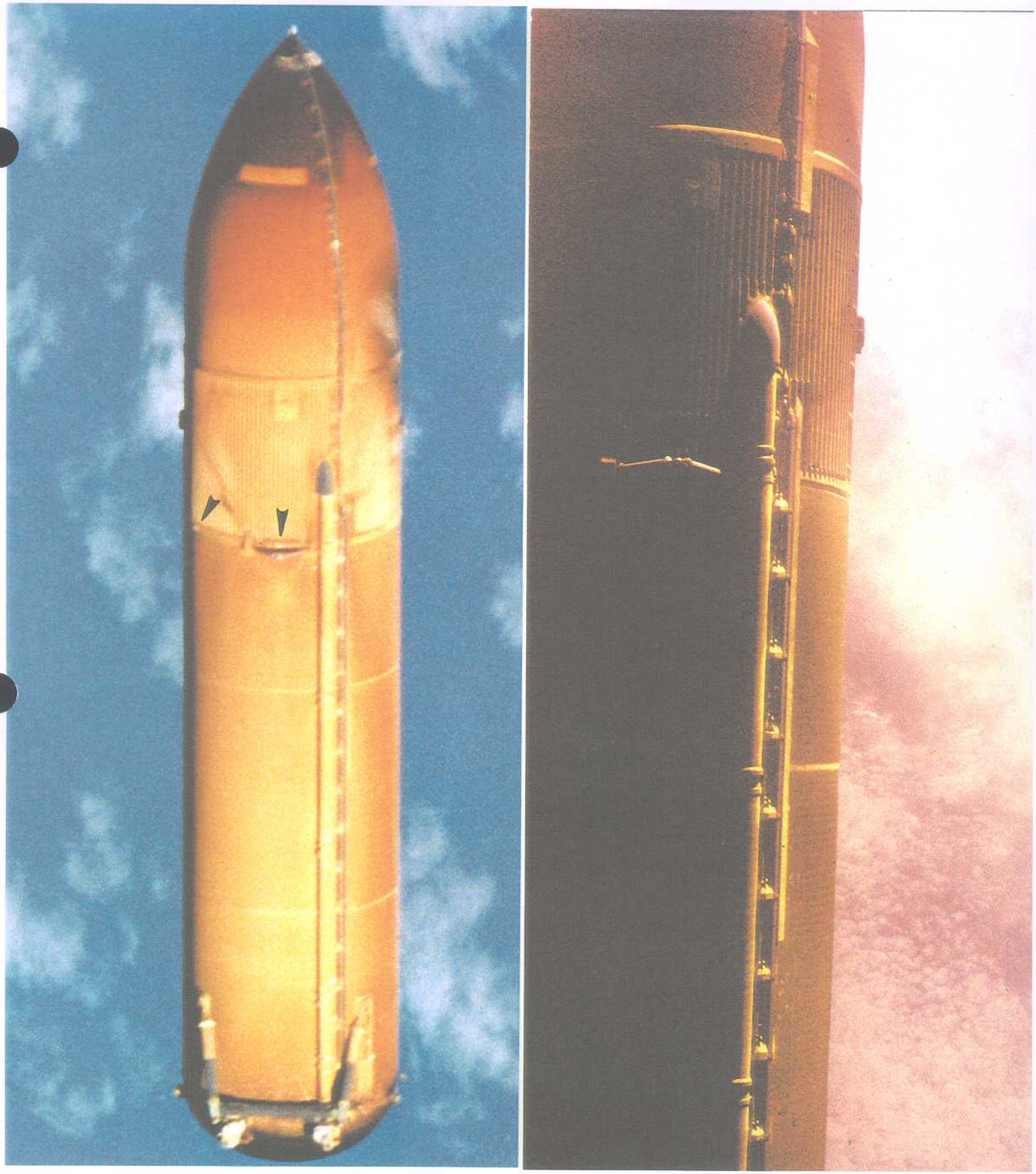

Photo 24: ET Intertank Area

Crew hand held image shows possible divots in the LH2 tank-to-intertank splice between the bipods and near the –Y thrust panel (arrows, left photo). However, view from the 35mm camera in the ET/ORB LO2 umbilical could not confirm the presence of the divots due to shifted field of view and deep shadow (right photo).

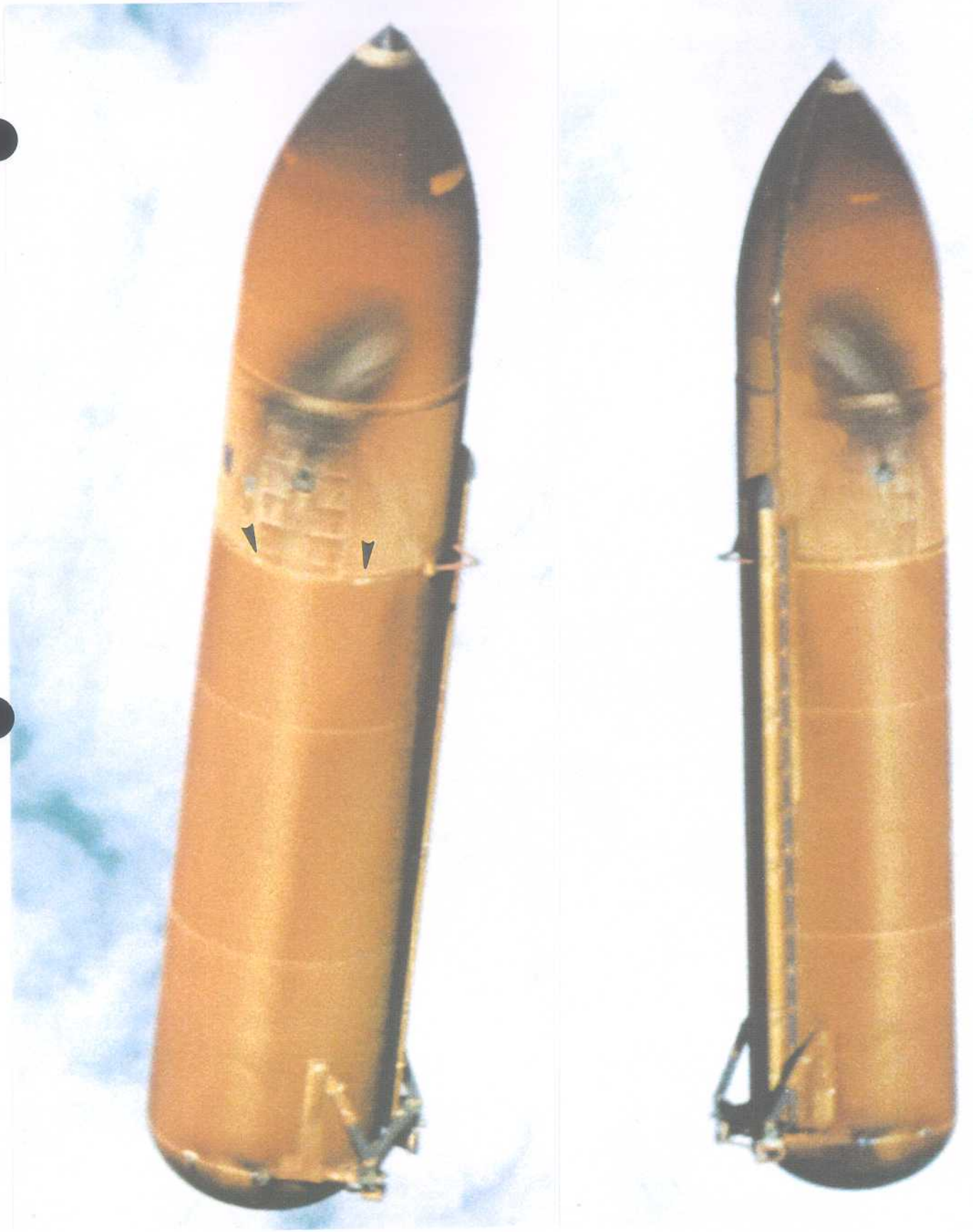

Photo 25: ET Thrust Panels

Crew hand held images show no large divots in either thrust panel - that would be discernible with the given image resolution and subject distance. Yet three 9-inch diameter divots are readily visible in the LH2 tank-to-intertank splice (arrows).

6.4 LANDING FILM AND VIDEO SUMMARY

A total of 17 films and videos, which included eight 35mm large format films and nine videos, were reviewed. There was not much detail for engineering assessment due to the dark conditions of a night landing.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach.

Runway centerline cameras showed right wing slightly low during final approach to counteract the effects of the crosswind, but then virtually level for main landing gear touchdown.

Drag chute deployment, which occurred before the nose wheel contacted the runway, appeared normal. No anomalies were detected from touch down through rollout.