# NASA Technical Memorandum

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# STS-26 SOLID ROCKET BOOSTER POST FLIGHT STRUCTURAL ASSESSMENT

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National Aeronautics and
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TECHNICAL MEMORANDUM

# STS-26 SOLID ROCKET BOOSTER POST FLIGHT STRUCTURAL ASSESSMENT

## 1.0 INTRODUCTION

This report is an account of the post-flight structural assessment of the STS-26 Solid Rocket Boosters (SRBs). The inspection was performed in Hangar AF of the Cape Canaveral Air Force Station on the John F. Kennedy Space Center in Florida, from September 30 to October 11, 1988.

The purpose of this document is two-fold. First, it is a record of the condition of the boosters after this flight. Secondly, it is intended to be a guideline for future post-flight structural assessments of the SRBs.

## 2.0 SUMMARY

Overall, the boosters were in good condition structurally. The only unforeseen problem was the damage to the Integrated Electronic Assembly (IEA) box cover. This appears to have been caused by water impact, and is not a next flight issue.

There are some other issues that warrant further investigation. A redesign of these components may be necessary.

1) Blast containers – Four of the eight containers did not function properly. The problem needs to be understood before a redesign is initiated.

2) Stiffener rings – A determination needs to be made if damaged rings are acceptable. Do the rings have to meet structural requirements or are they considered a "fuse" and allowed to fail?

3) Ordnance ring – The linear-shaped charge housing was damaged severely due to the blast pressure. This condition should be investigated for possible redesign.

4) SRM stiffener ring stubs – Three cracks were found on the stiffener ring stubs. This is mainly a reuse issue.

## 3.0 COMPONENT EVALUATIONS

### 3.1 Aft Skirt Assembly

#### 3.1.1 Aft Skirt Structure (Reference Figure 1)

The left and right aft skirts were visually inspected for signs of damage. The areas checked and their respective conditions were:

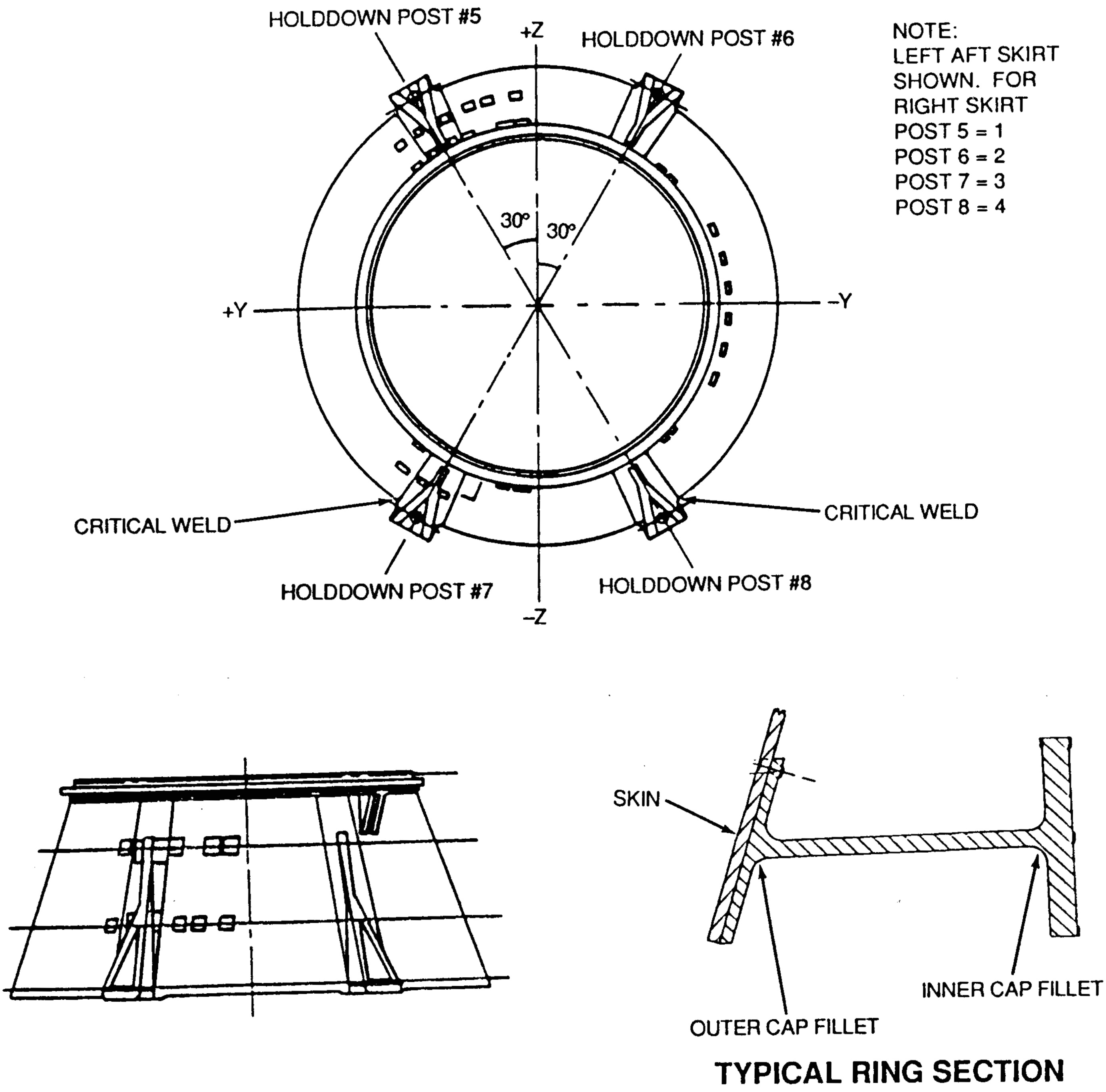



Figure 1. Aft Skirt structure.

1) Post-to-Skin Welds – Insulation was removed from the lower portions of the weld areas so that they could be inspected. No cracks were observed in any of the weld regions. A slight meridional scratch was noticed on the left side of post No. 7 on the left aft skirt however. The scratch was located adjacent to the weld/forging interface at approximately the elevation of the aft ring centerline. This was reported and subsequent non-destructive evaluation (NDE) will determine if this presents a problem.

2) Interior Rings – The aft side inner and outer flange-to-web fillets were inspected for cracking and/or deformation. No cracks or obvious deformation were observed. A paint crack approximately 8-in. long in the aft ring inner cap fillet at Rib No. 48 of the left skirt was found. This indicates that yielding or excessive deformation may have occurred. United Space Boosters, Inc. (USBI) agreed to request that further NDE be performed in this area. Gouges were also observed in the outer cap fillet of the right skirt at Rib No. 14. They appeared to be due to assembly or TPS removal and USBI agreed to document them on a problem report.

3) Ring-to-Skin Fasteners – Sealant caps were in place over all of the fasteners. There was no evidence of sheared bolts on any of the rings.

4) Gussets – Each gusset was visually checked and showed no sign of buckling.

5) Horizontal and Vertical Tabs – The connections of the hold-down post tabs to the aft ring were checked and no sheared fasteners were found.

6) Forging – The footpad holes showed no signs of broaching (caused by improper stud ejection) and the tension post footpads showed no obvious signs of dishing.

7) Kick Ring Bolts – All of the inner and outer kick ring bolts were in place. Sealant covered each bolt, thus precluding further inspection.

8) Forward Ring Weld – Foam covered the inside surface of the weld and insulation covered the outside, thus preventing an inspection.

### 3.1.2 Thrust Vector Control (TVC) System (Reference Figure 2)

The TVC hardware was inspected and no signs of structural damage were found. Particular attention was given to the adjusto bolts and lugs that secure the lower frames to the aft ring; the fuel supply module (FSM) guard and attach brackets; the hydraulic reservoir guard and attach brackets; and the exhaust duct.

### 3.1.3 Aft Booster Separation Motors (BSMs) (Reference Figure 3)

The aft BSM support structure was inspected and no damage to the frames was observed. All bolts were also in place.

## 3.2 Blast Container (Reference Figure 4)

STS-26 was the first flight for the redesigned blast container with the debris containment device. No structural damage was observed in the container housing

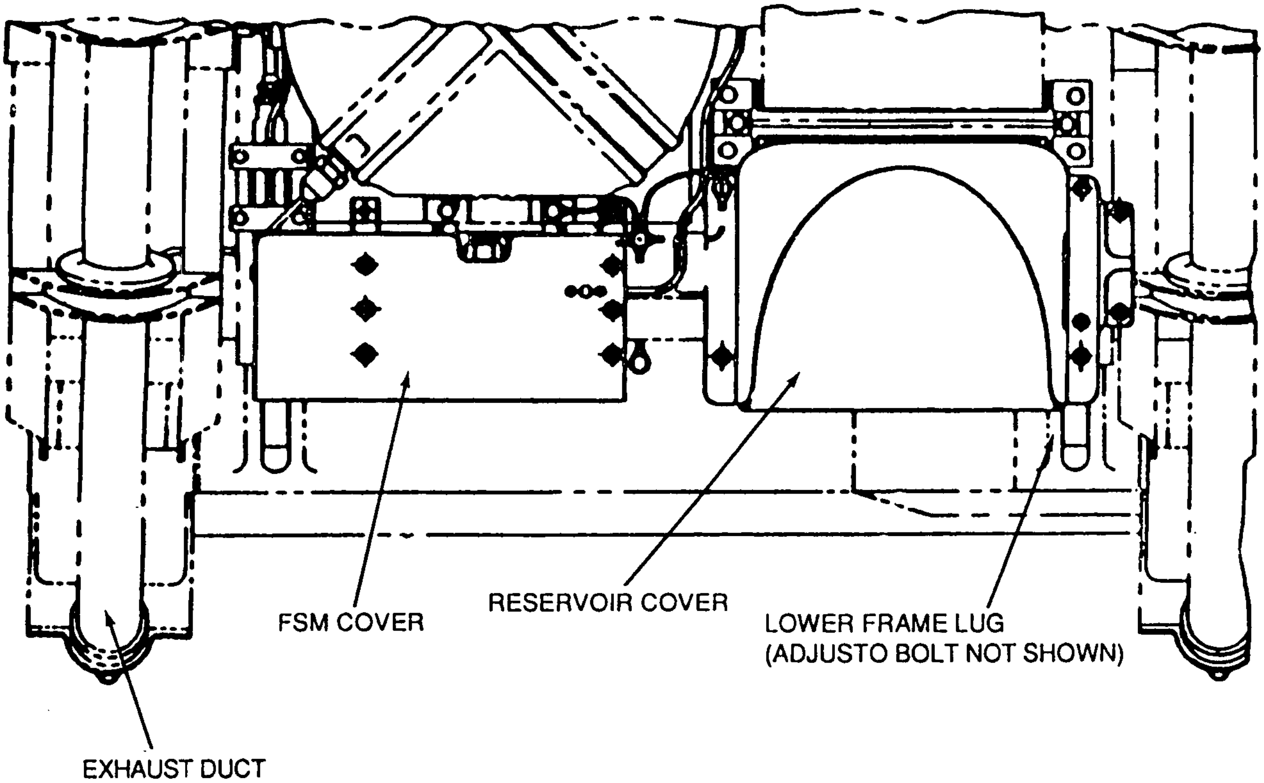



Figure 2. Thrust Vector Control System hardware.

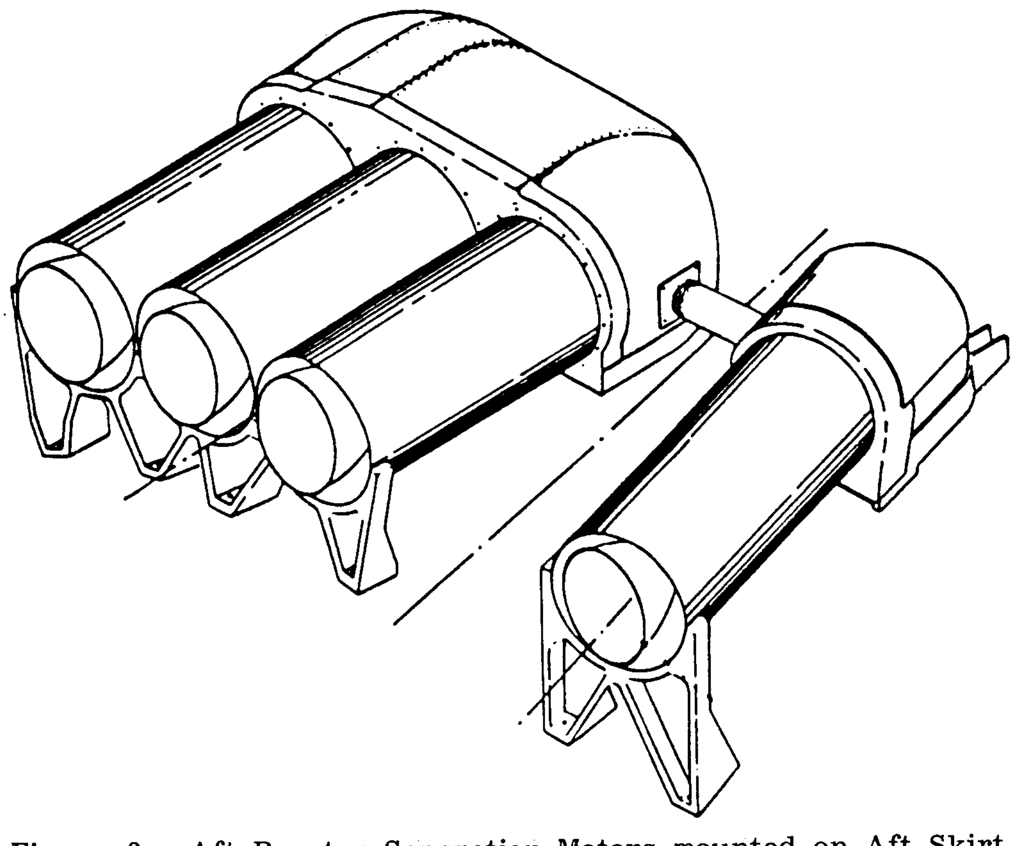


Figure 3. Aft Booster Separation Motors mounted on Aft Skirt.

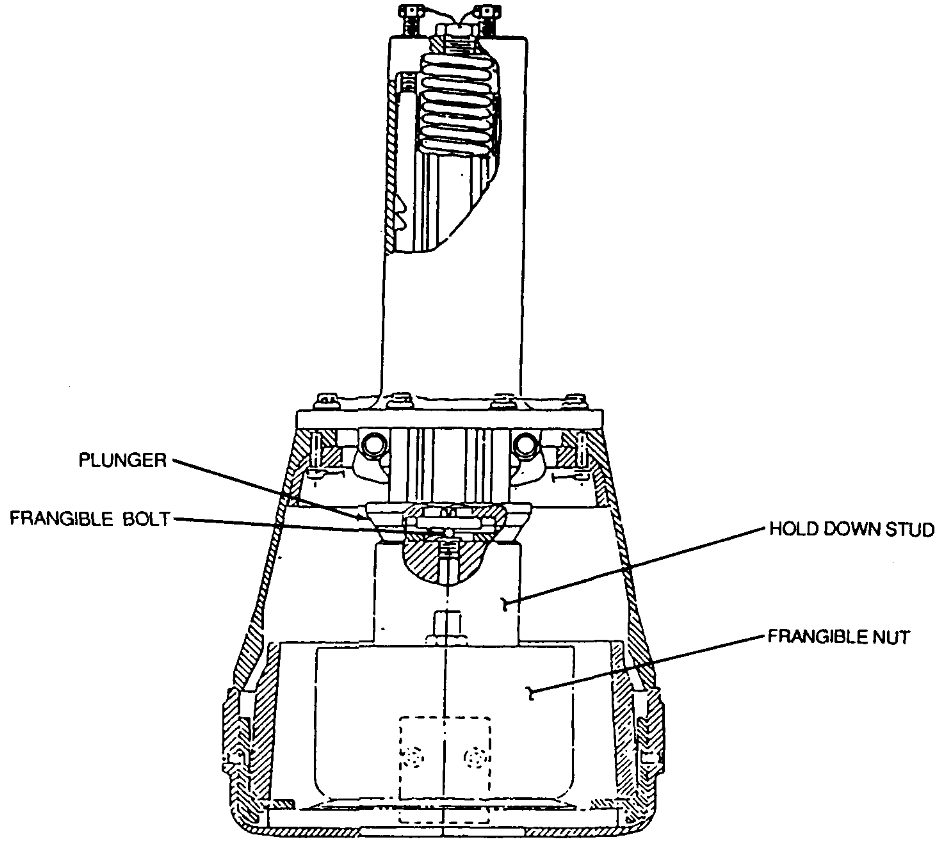



Figure 4. Blast Container with debris containment device.

which sees a high pressure load from the pyro-technic blast. Several interior clips, which hold the spherical washer in place, had some metal removed during the blast.

The plunger mechanism functioned properly at four of the eight posts and the hole in the bottom of the container was sealed. At one post, the plunger was seated but material was missing from the container. This indicates that the hole was plugged sometime during the flight, not at the initial blast. At three other posts, a large piece of the nut prevented the plunger from seating and there was sufficient room for debris to fall out of the hole. Reconstruction of the containers and frangible nut pieces confirmed that material escaped from four of eight containers.

The failure of the plunger to plug the hole is most likely due to two factors. The first is that initial stud vibratory acceleration, due to preload lost when the frangible nut breaks, is much greater than the acceleration of the plunger due to the spring force. Since the bolt accelerates with the stud, and there is a gap between the plunger and the bolt, the bolt sees an impact force as it contacts the plunger. This force may be greater than the tensile strength of the bolt.

The other factor is that the broken frangible nut may be contacting the beveled sides of the plunger as it travels downward, thus jamming the plunger before it seats.

These possibilities are being investigated as of this writing, and a redesign of the internal blast container components, to provide better performance, is forthcoming.

3.3 Systems Tunnel (Reference Figure 5)

The systems tunnel of each SRB was visually inspected while the boosters were intact on the rail cars. No damage was observed to either tunnel prior to cover removal. The auxiliary K5NA tunnel that contained the field joint heater cables was intact. A complete inspection of the covers and floorplates after cover removal was not done. However, no obvious structural damage was reported.

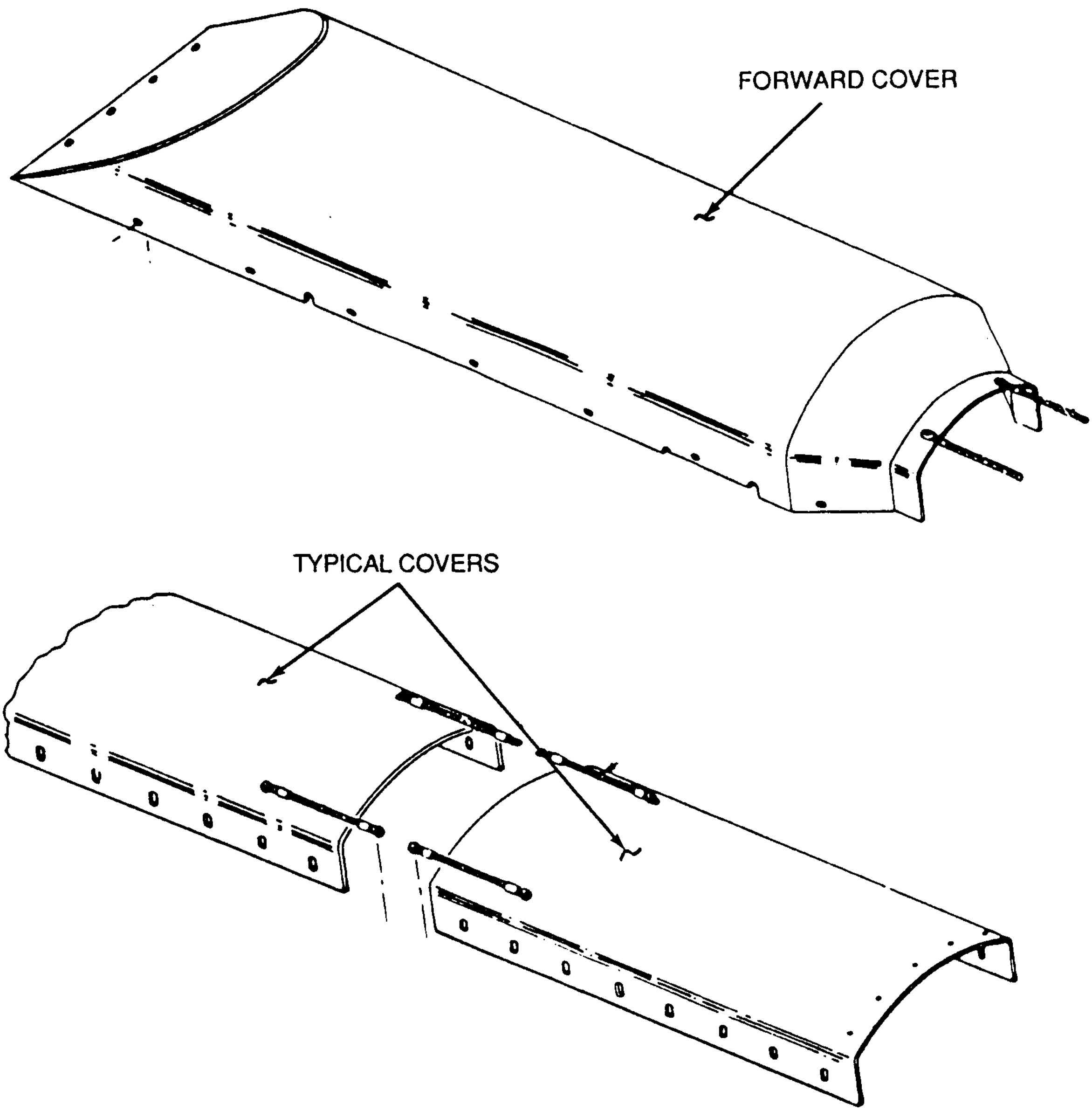



Figure 5. Systems Tunnel Covers.

3.4 Stiffener Rings (Reference Figure 6)

The video tape of water impact showed a large geyser of water moving up one side of the left-hand booster. The right-hand booster had a smaller, less spectacular entry. We hypothesized the left-hand booster stiffener rings would sustain more damage. The complete opposite proved to be true. On the left side, the stiffener rings and their fasteners were in good condition. No structural damage was observed. All three stiffener rings on the right-hand booster were damaged. The following is a list of the damage sustained.

1) Forward ring – The ring was bent radially inward approximately 0.50 in. at the 160-deg location. A 3-in. crack through the bolt hole was evident in the web at this location. Also, 38 fasteners in the area had failed in shear.

2) Center ring – The ring was bent radially inward approximately 0.25 in. at the 160-deg location. A 5-in. crack through the bolt hole was evident in the web at this location. A total of 30 fasteners failed in this area.

3) Aft ring – The ring had a 7-in. crack through the bolt hole and continuing along the stiffener ring web. A total of 20 fasteners failed in this area.

All three rings had local buckling on either side of the damaged area. Typically, this out-of-plane deformation of the web would occur about 20 deg away from the crack centerline. This buckling was caused by the inward displacement of the ring which put part of the web in compression. These areas corresponded to the same locations where cracks were observed on the motor case stiffener ring stubs.

Permanent deformation was observed in many of the holes on all three rings in the vicinity of the cracks and buckled regions. This indicates that the rings carried a large in-plane load which was probably caused by cavity collapse pressure on the motor case.

The insta-foam on the aft side of the three stiffener rings was missing from 130 to 190 deg. This indicates that the water impact loads were high in this location.

3.5 ET Attach Rings (Reference Figure 6)

Prior to flight, three areas were determined to have low margins of safety, as shown in USBI ET Attach Ring Stress Analysis (USBI-ANAL-32-88). They include the systems tunnel splice, cap splices, and the strut lugs. These sections were examined more closely during post-flight inspection.

The ET attach rings were visually inspected prior to removal from the motor case and after disassembly. Before removal, the condition of the insta-foam on the rings could be inspected. The foam on the forward edges was rough and discolored, but in good condition. No metal was exposed. Both rings had a section of insta-foam missing on the aft side. There was approximately 60 deg of foam missing, exposing the rings. This area was clean and not covered in soot as was the other hardware in the vicinity. The missing foam location corresponded to the foam damaged on the three stiffner rings aft of the ET attach ring. Apparently the damage was caused by cavity collapse at water impact.

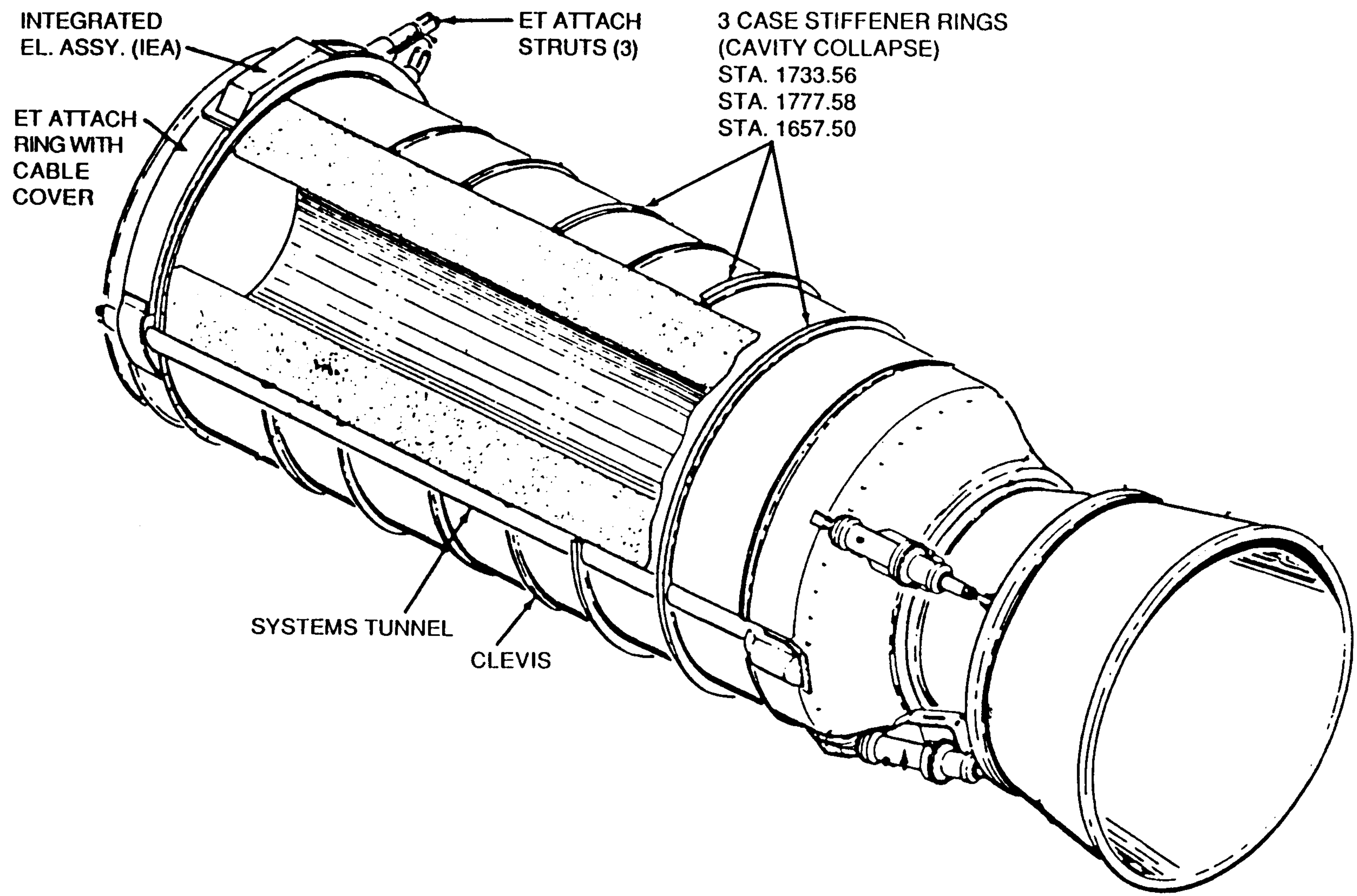



Figure 6. SRM Aft Segment.

The hardware on the rings was in good condition. All of the splice plates and web-to-tang holes were inspected, and no cracks or deformation were evident. The paint sealer between the cap and the web was checked for cracks, which would indicate relative motion between the parts, no cracks were noted. Some of the fasteners in the critical splice areas were saved for metallurgical examination. Visually the fasteners appeared in good condition, without deformation.

Possible damage was seen on a right-hand SRB intercostal. Paint was missing from the intercostal and the adjoining web, appearing as if there was contact between them. However, this could be the result of damage encountered during retrieval. The IEA cover was missing in this region, thus the intercostal was exposed to sea water during towback. Also, several cables were loose in this area and they could have contacted the intercostal.

The In-Harbor Tow Bracket on the left-hand SRB was bent forward about 1 in., also the six bolts which attach the bracket to the motor case tang were sheared. These bolts fasten the ET attach ring web to the tang. The adjoining lightning covers on the attach ring, which attach to the bracket, also sustained damage. This problem was the result of the SRB contacting the recovery ship during the retrieval process. As the ship was negotiating a turn, high swells pushed the SRB into the hull. The ship's fenders, designed to prevent this situation, were not adequate.

## 3.6 Aft IEA Box

One of the IEA box side covers on the right-hand SRB was missing. This cover has the same circumferential location as the damaged stiffener rings. All 37 rivets which attach the side cover to the center cover had failed, also the twelve 0.25-in. bolts which fasten the side cover to the cap were sheared. The damage appears to have been caused by water impact. The failed fasteners indicated that the cover was moving forward; this load is what would be expected during splash down due to the water spray. The cleanliness of the IEA box and the inside surfaces of the ET attach ring also suggest water impact. This area is exposed with the side cover off. The adjacent hardware is heavily sooted in this vicinity. Other damage was also evident as a result of the cover failure. The connecting lightning cover was bent and four fasteners had failed. Also, the center portion of the IEA cover was bent with three broken fasteners. Figure 7 summarizes the damage to the IEA box area.

## 3.7 Solid Rocket Motor Case

The motor case segments visually appeared in good condition. There was no evidence of structural damage on the clevis or tang. There were several areas on the external surface of the motor case where paint was missing. Typically, these areas were a maximum of 4 $in.^2$.

The ET attach ring stubs were inspected for cracks and hole elongation and none were evident. Three cracks were found on the right-hand SRB stiffener ring stubs. The aft ring stub had a crack at 142 deg, and the center stub had cracks at 186 and 188 deg. These cracks ran between the fastener hole and the outboard edge of the stub. The location of the cracks corresponds to the buckled area of the stiffener rings.

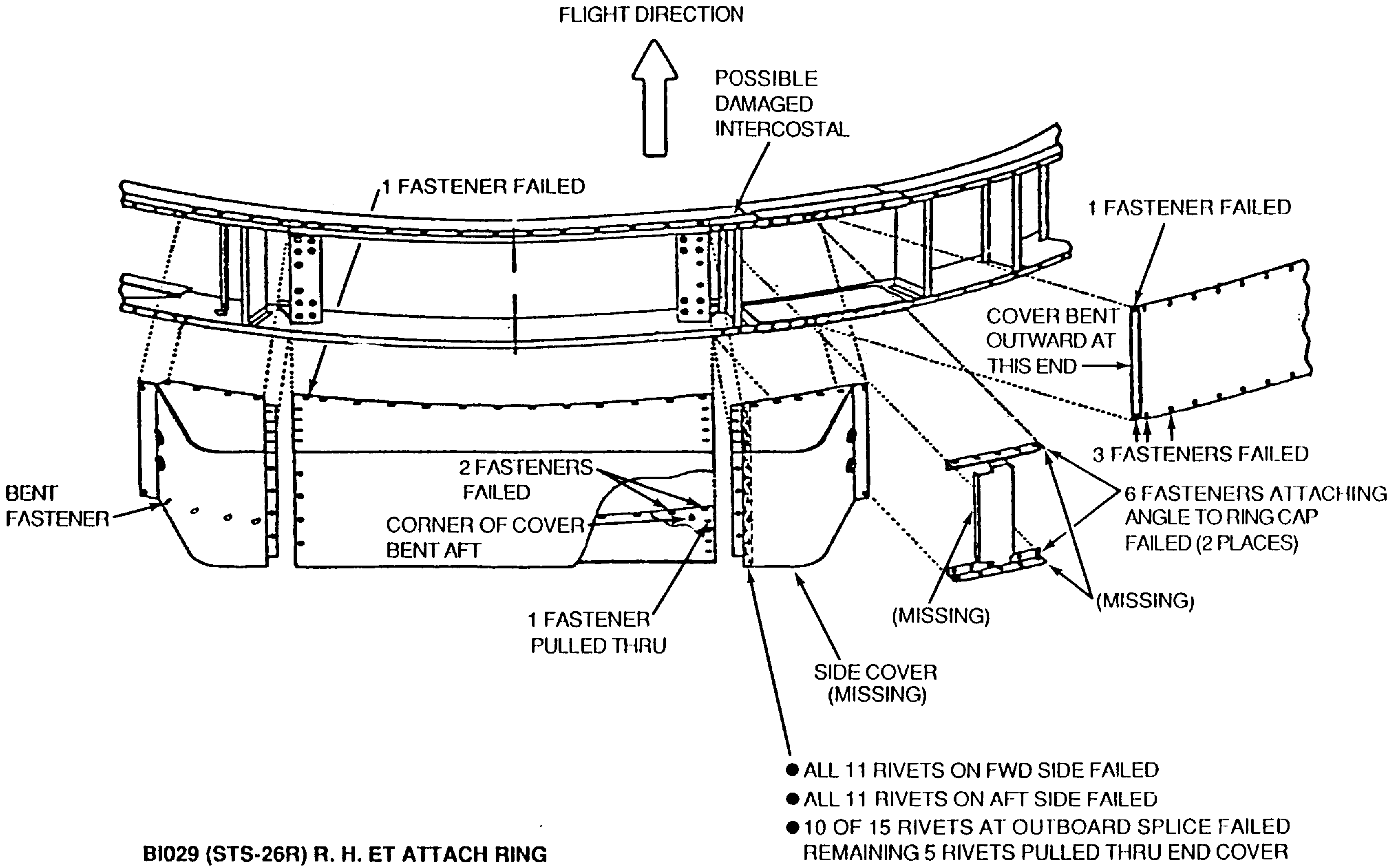
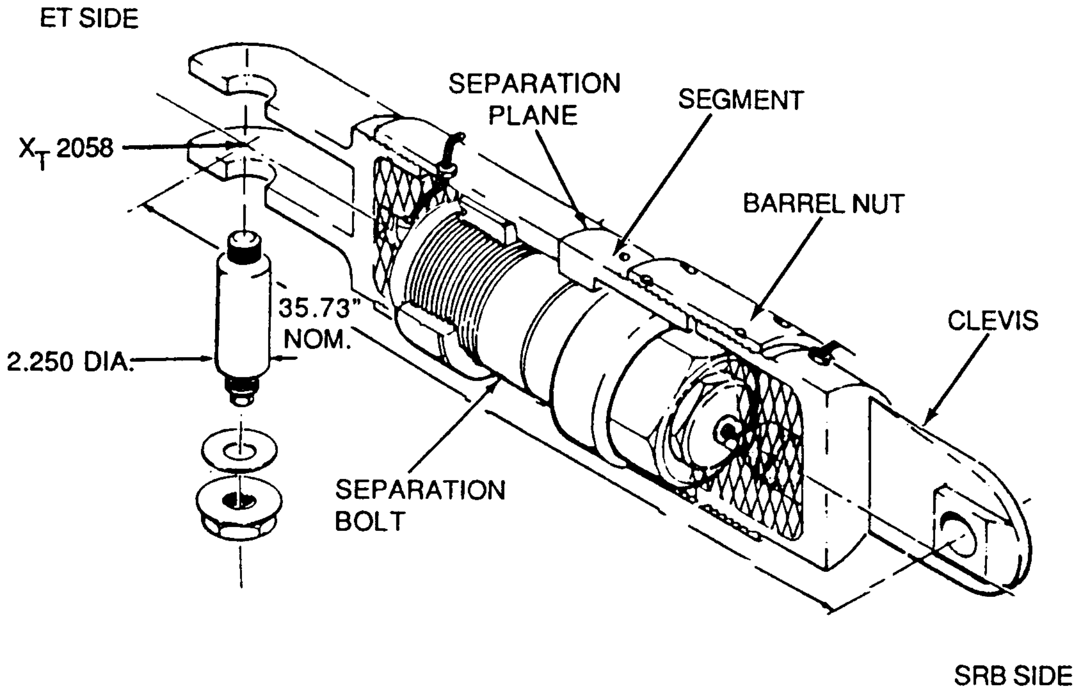



Figure 7. IEA Box damage.

3.8 Aft Attach Struts (Reference Figure 8)

The SRB half of the upper, diagonal, and lower struts are separated into three components: the clevis, the strut segment, and the barrel nut that connects the clevis to the segment. The SRB half of the separation bolt which is internal to the strut segment is recovered as well as the SRB clevis attach pin. Score lines were seen on all of the attach pins. The lines were shallow so only the surfaces of the pins were damaged. Also, some local deformation was seen on the edge of the flat bearing surfaces of several strut segments. These surfaces are in contact with the separation bolts. The deformation was very slight and was not considered to be a problem.




**NOTE: UPPER STRUT IS SIMILAR EXCEPT THAT THE SEGMENT HAS A 360° CABLE CONNECTOR FLANGE**

Figure 8. Typical Lower or Diagonal Strut.

3.9 Forward Skirt (Reference Figure 9)

No damage was observed to either forward skirt. The areas checked were: the dome, camera assembly, exterior thrust post, systems tunnel floor, interior skin, lower clevis pin holes, the access door area, interior structural rings and beams, interior welds, and the weld between the access door J-stiffener and the upper ring web at the parachute attach point location.

3.10 Ordnance Ring (Reference Figure 10)

The structural parts of the ordnance ring appeared to function normally. The fracture plane was clean and no obvious deformation was seen in the lower pin holes that mate with the forward skirt.

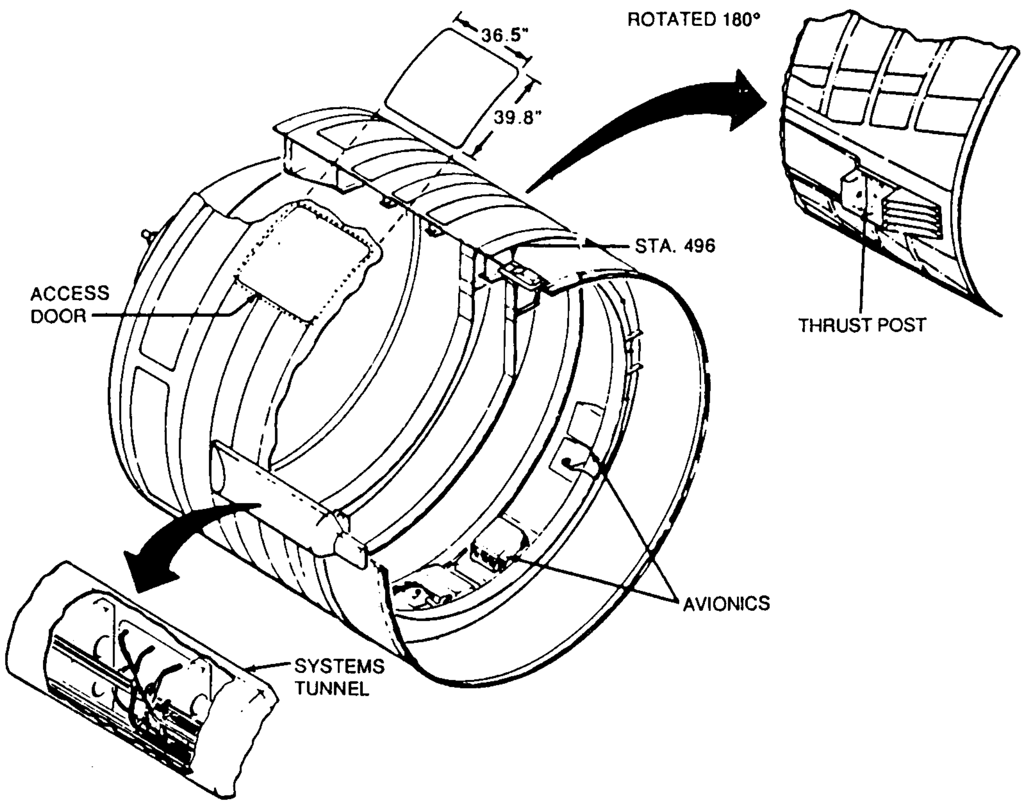



Figure 9. Forward Skirt Assembly.

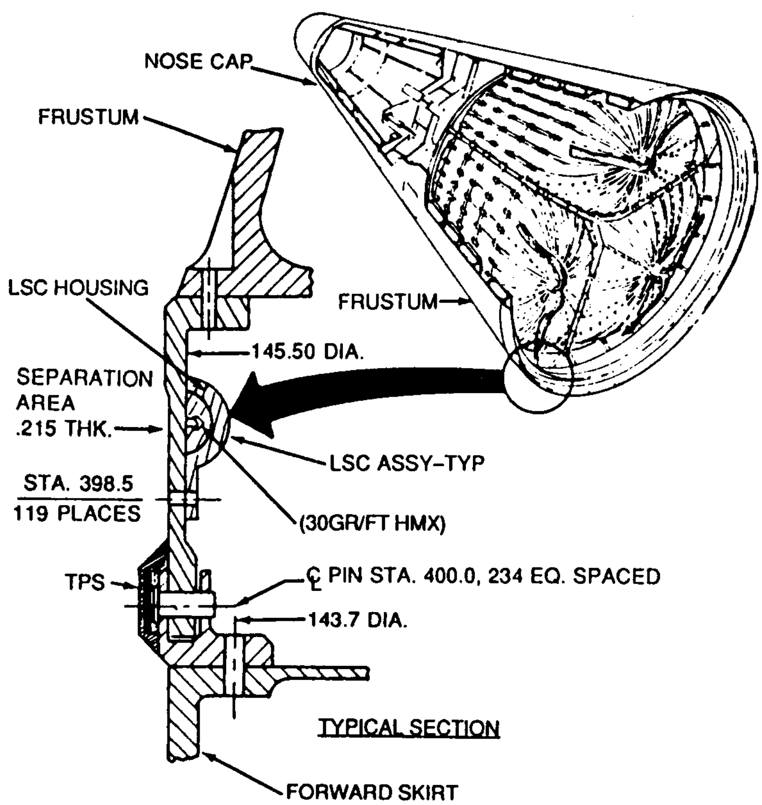



Figure 10. Ordnance Ring Assembly.

The linear-shaped charge (LSC) housing of each ring assembly was severely damaged, however. The housing failed at numerous locations around the circumference of the ring. Bolts that secure it to the ring pulled through the slotted holes in the housing in many places and the housing holes were excessively damaged.

The LSC housing is reinforced intermittently by backup plates. All of the damage was seen in the spans between reinforcements. A possible fix would be to add more backup plates to shorten the unreinforced spans.

This condition has been observed on previous flights and is caused by the blast pressure of the LSC. None of the housing sections actually came off but some almost did. This is a concern because a loose piece of metal that size could possibly cut a parachute line.

## 3.11 Frustum

### 3.11.1 Frustum Structure (Reference Figure 11)

The interior of each frustum was inspected and no damage was seen. Due to low margins of safety, shown in the USBI Frustum Stress Analysis (USBI-ANAL-74-87), a request was made to remove four bolts that connect the top ring of the frustum to the BSM support beam. These fasteners are loaded in tension during flight and will be sent to USBI-Huntsville for evaluation, following removal. Sealant caps covered the fasteners during the inspection, indicating that the bolts were still in place.

### 3.11.2 Forward Booster Separation Motors (Reference Figure 11)

The four motors in each frustum showed significant yielding in the flange around the edge of the nozzle exit cone. No dimpling or distortion of the nozzle surface was seen, however. The end ring that bolts to the nozzle flange also showed significant yielding in the corresponding locations. This condition is expected and is caused by the torque put on the ring by the opening of the exit cone cover at BSM ignition.

### 3.11.3 Isogrid Structure (Reference Figure 12)

The isogrid structure in each frustum supports the main parachutes prior to deployment. The corner fittings that are part of the attachment of the isogrid to the frustum see a high inertial load at frustum separation. Three fasteners at each corner fitting were shown to have negative margins of safety in shear bearing in the USBI Decelerator Subsystem Stress Analysis (BPC-ANAL-61-87). Paint cracks around the sealant caps on several of these bolts were observed and a request was made to remove nine corner fitting bolts from each isogrid assembly so that the holes could be inspected for deformation. USBI concurred with this request and the data will be sent to USBI-Huntsville and MSFC for evaluation.

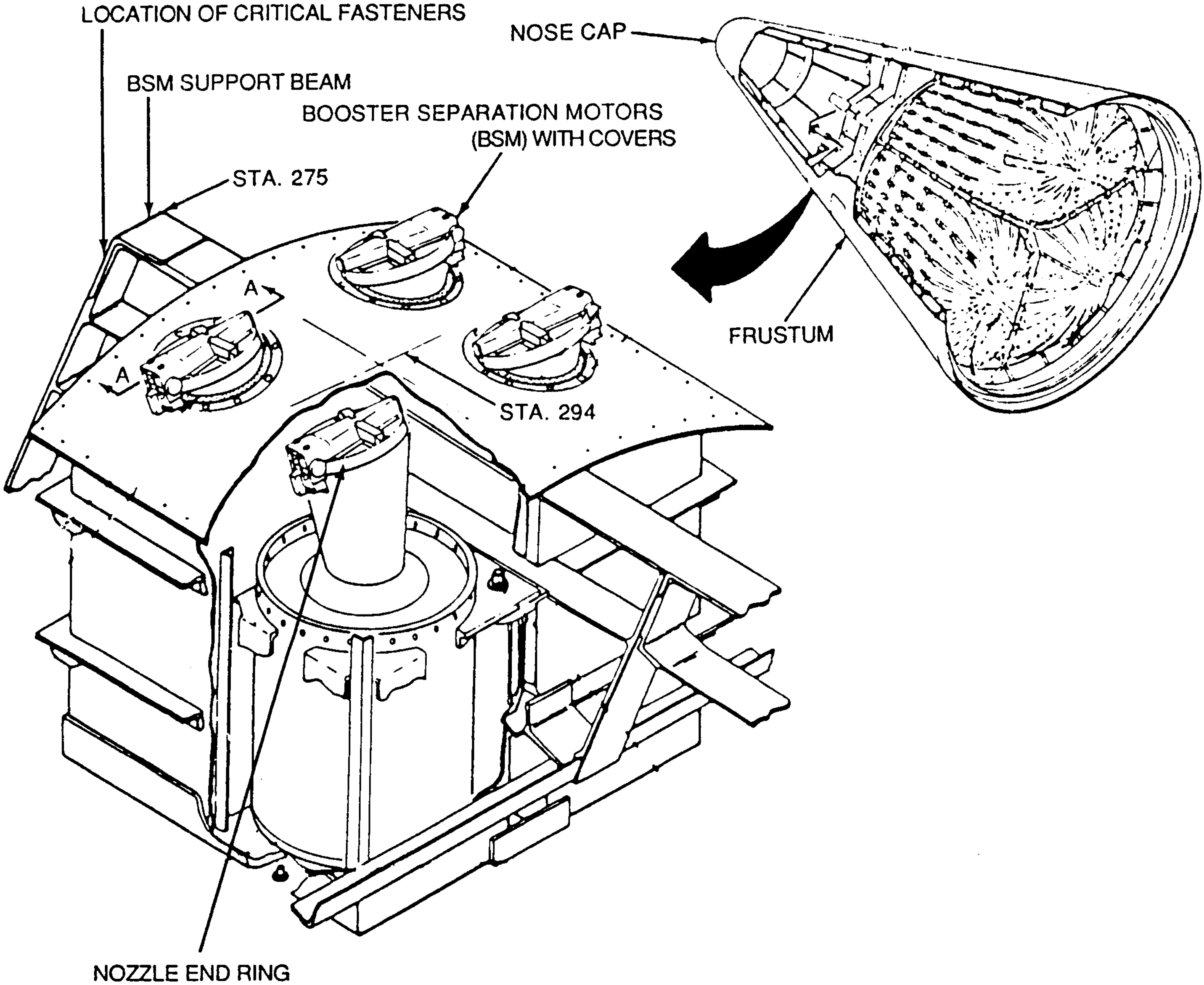



Figure 11. Frustum with Forward BSMs.

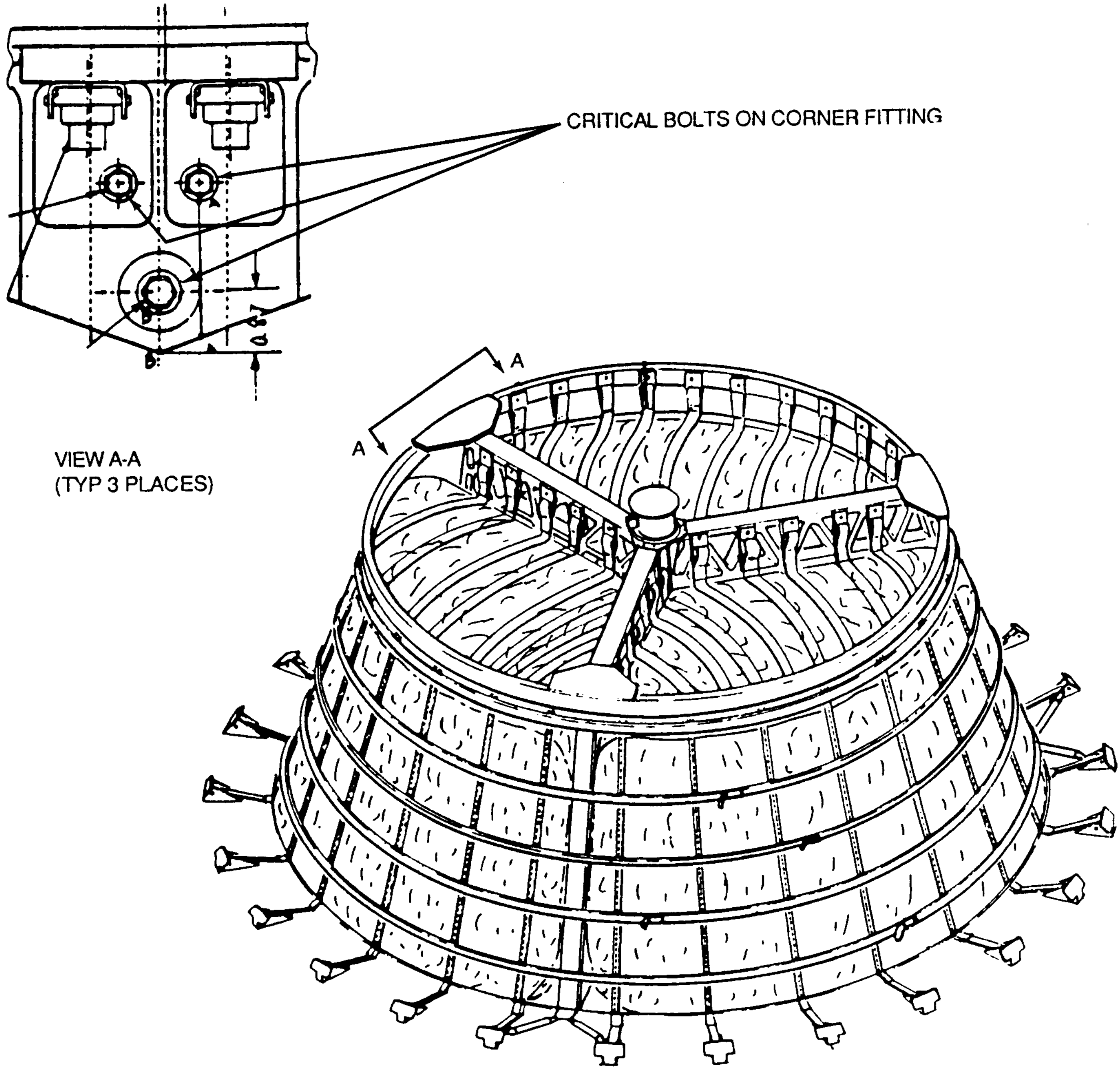



Figure 12. Main Parachute Support Structure
with parachutes in place.

APPROVAL

STS-26 SOLID ROCKET BOOSTER POST FLIGHT
STRUCTURAL ASSESSMENT

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

JAMES C. BLAIR
Director, Structures and Dynamics Laboratory

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**16. ABSTRACT**

A post-flight assessment of the Space Shuttle's Solid Rocket Boosters was conducted at the John F. Kennedy Space Center in Florida after the launch of STS-26. The two boosters were inspected for structural damage and the results of this inspection are presented in this report. Overall, the boosters were in good condition. However, there was some minor damage attributed to splash down. Some of this damage is a recurring problem. Explanations of these problems are provided.


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