Forward Skirt Structural Testing on the Space Launch System (SLS) Program

Joe Lohrer

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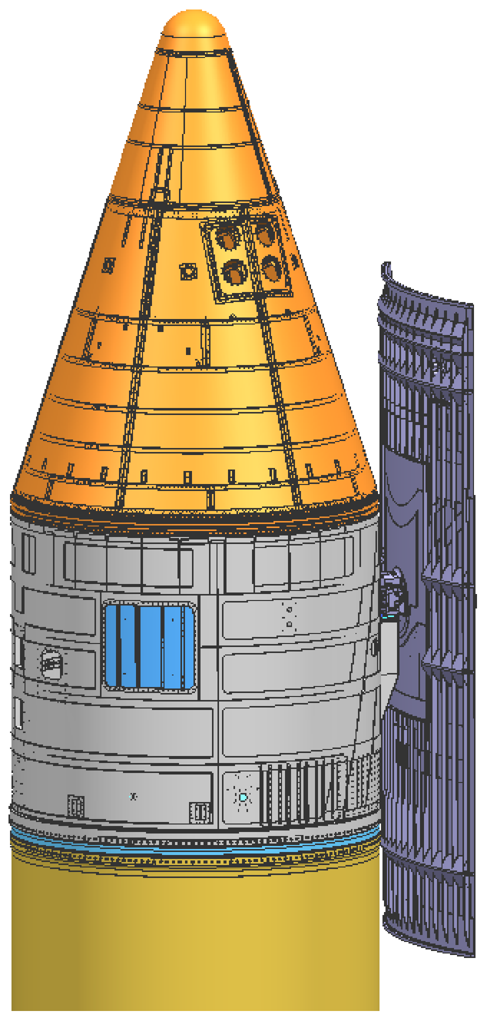
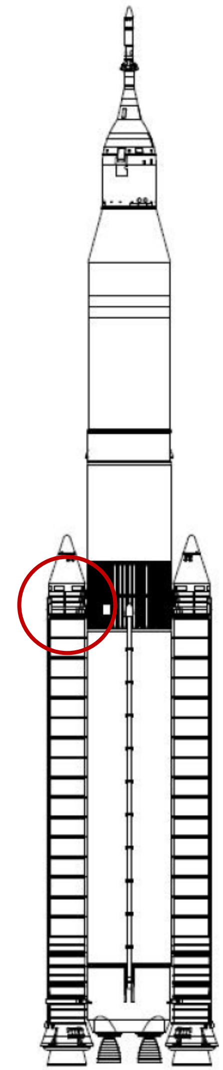
Introduction

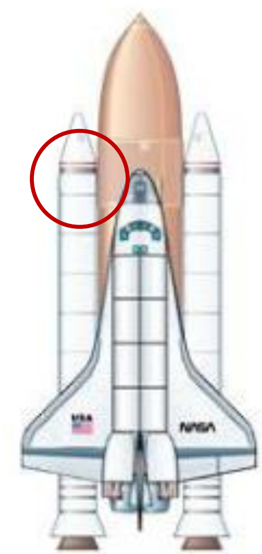
- Structural testing was performed to evaluate Space Shuttle heritage forward skirts for use on the Space Launch System (SLS) program.
- Testing was required because SLS loads are approximately 35% greater than shuttle loads.
- Two forwards skirts were tested to failure.

Forward Skirt





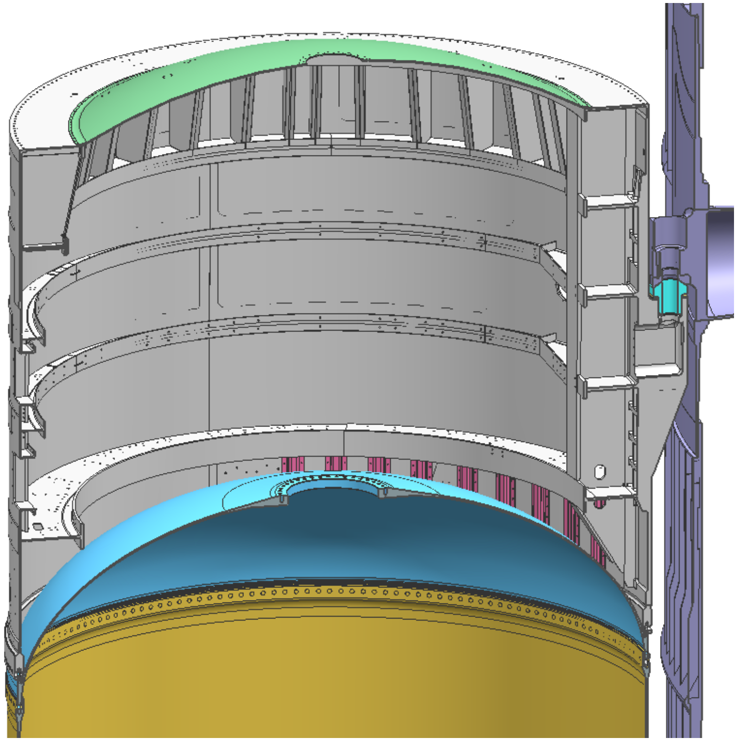
SLS Vehicle

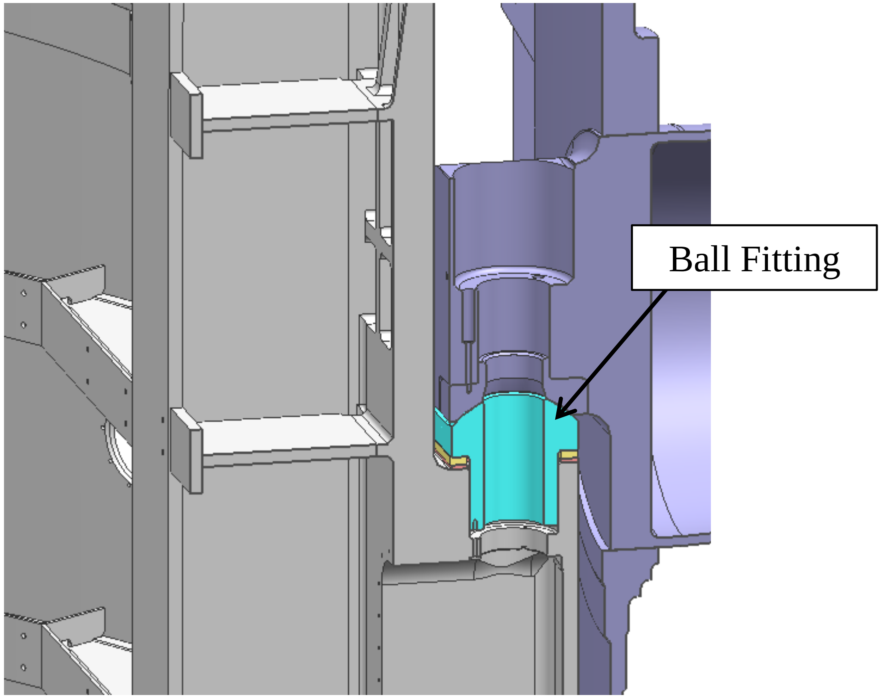


Shuttle

Purpose of Forward Skirt

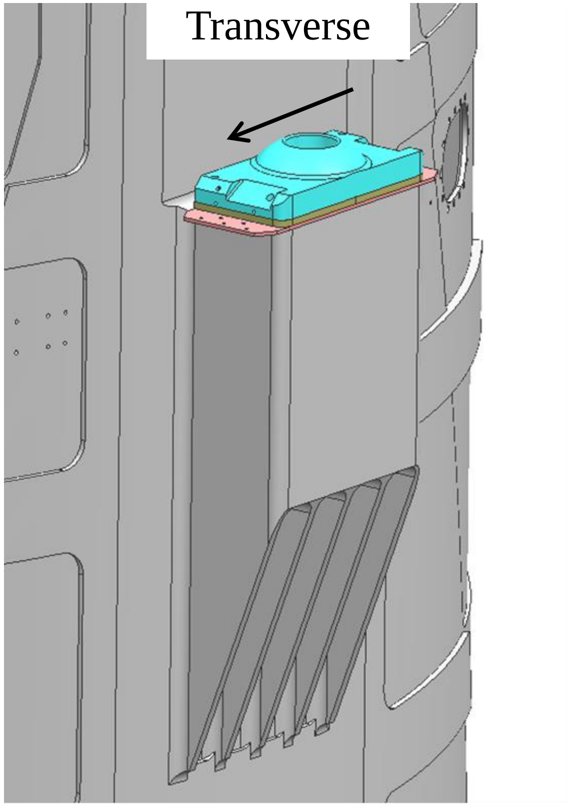
- Forward skirt transfers thrust from the solid rocket booster to the core vehicle during flight. A spherical interface allows only translation loads to be carried and not moments.
- The highest axial loads are compressive and reacted through the ball fitting instead of the separation bolt (not shown).   Because of this the separation bolt was not included in the testing.

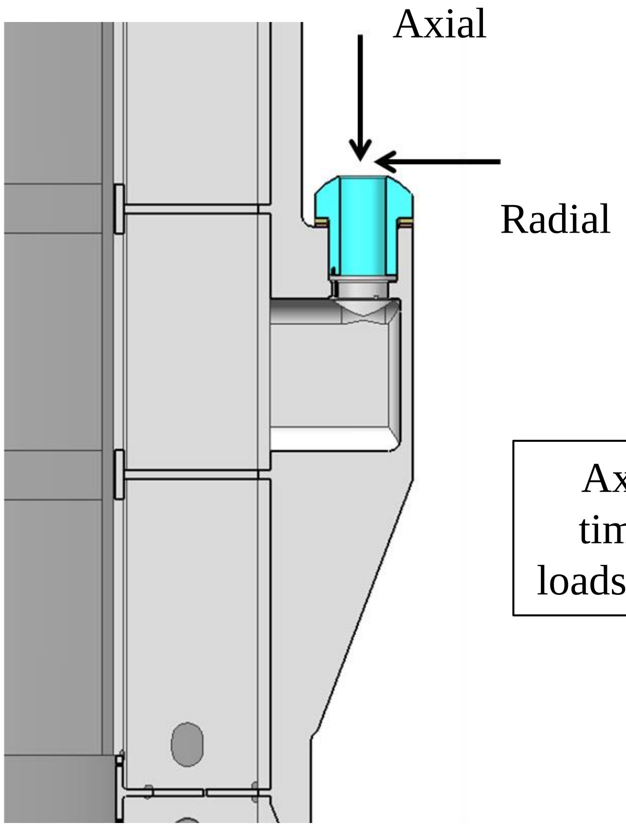




Forward Skirt SLS Loads

- Axial loads during ascent increased 35% over shuttle.
- Radial loads during liftoff increased 68% (inward) and 200% (outward) over shuttle.
- Transverse loads were similar to shuttle.

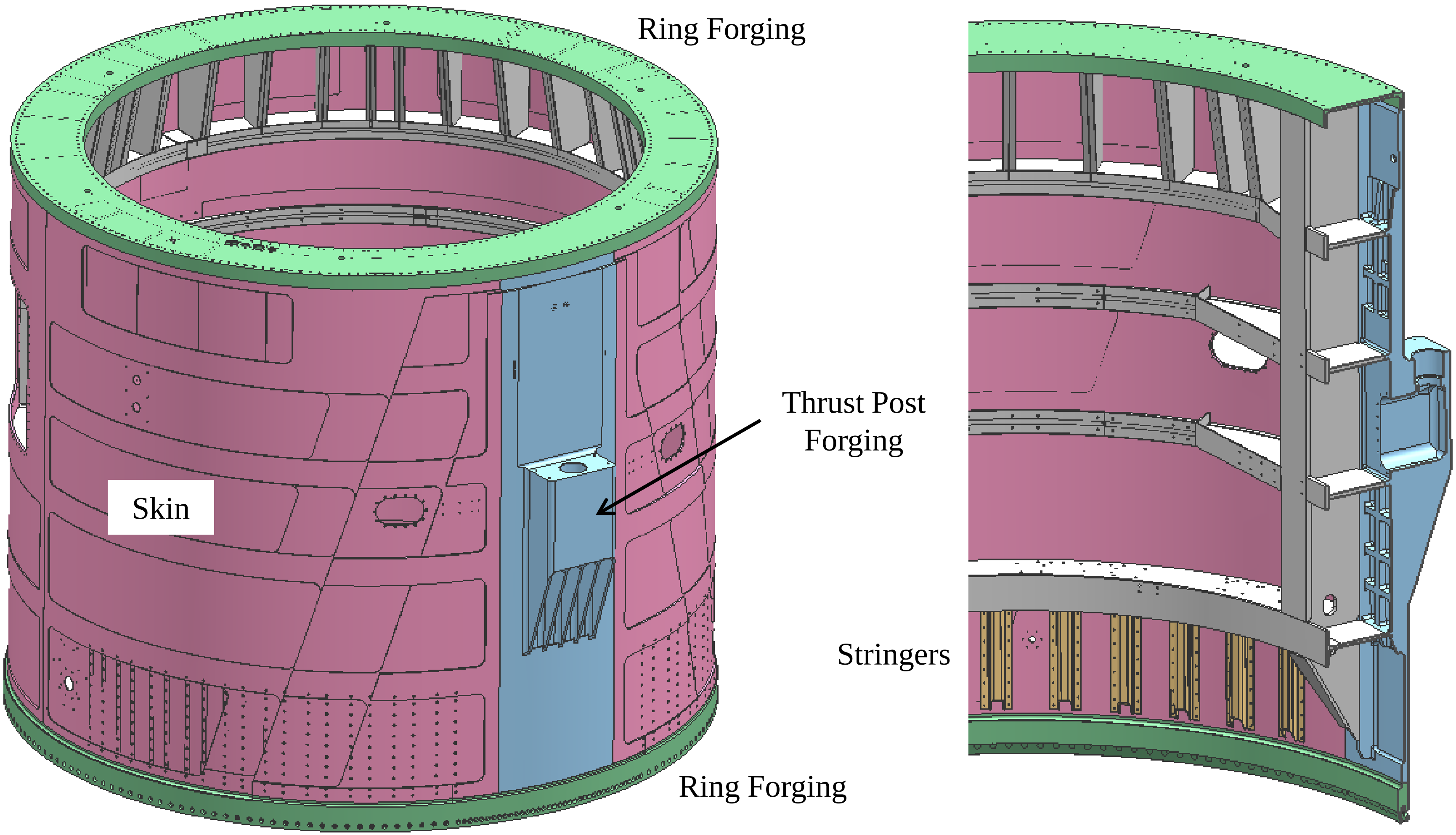




Axial loads are 10 to 20 times greater than radial loads depending on the event

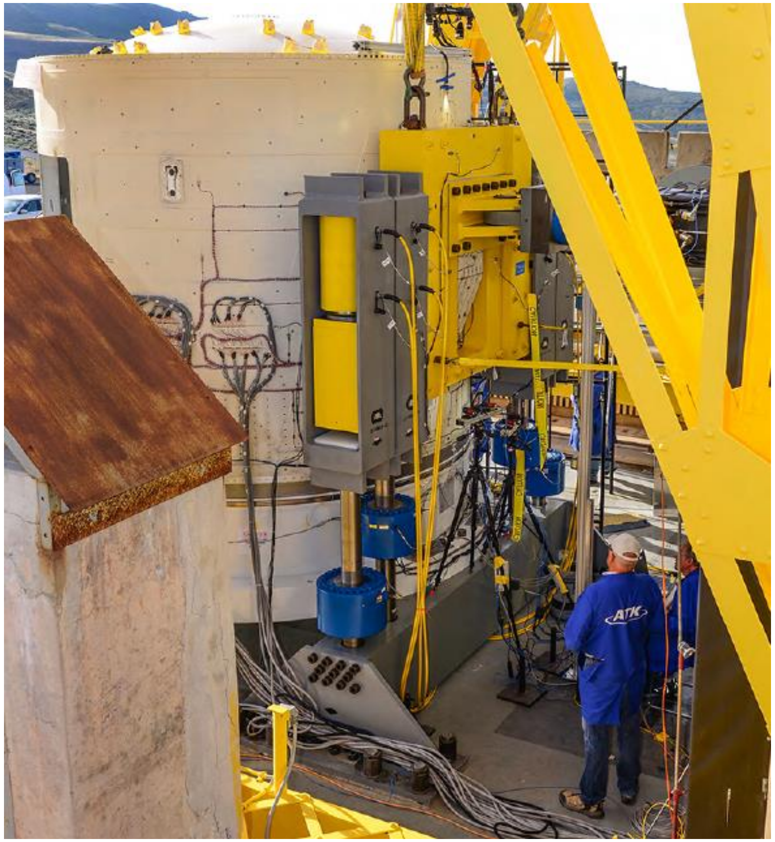
Forward Skirt Design

- Aluminum 2219 weldment.   Lowest properties occur in the thrust post.

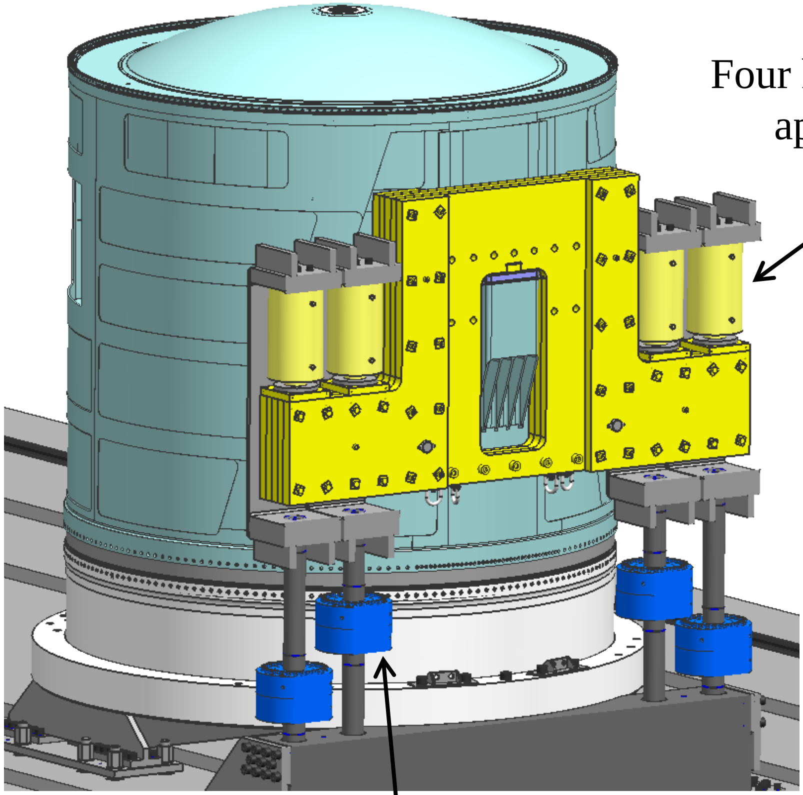


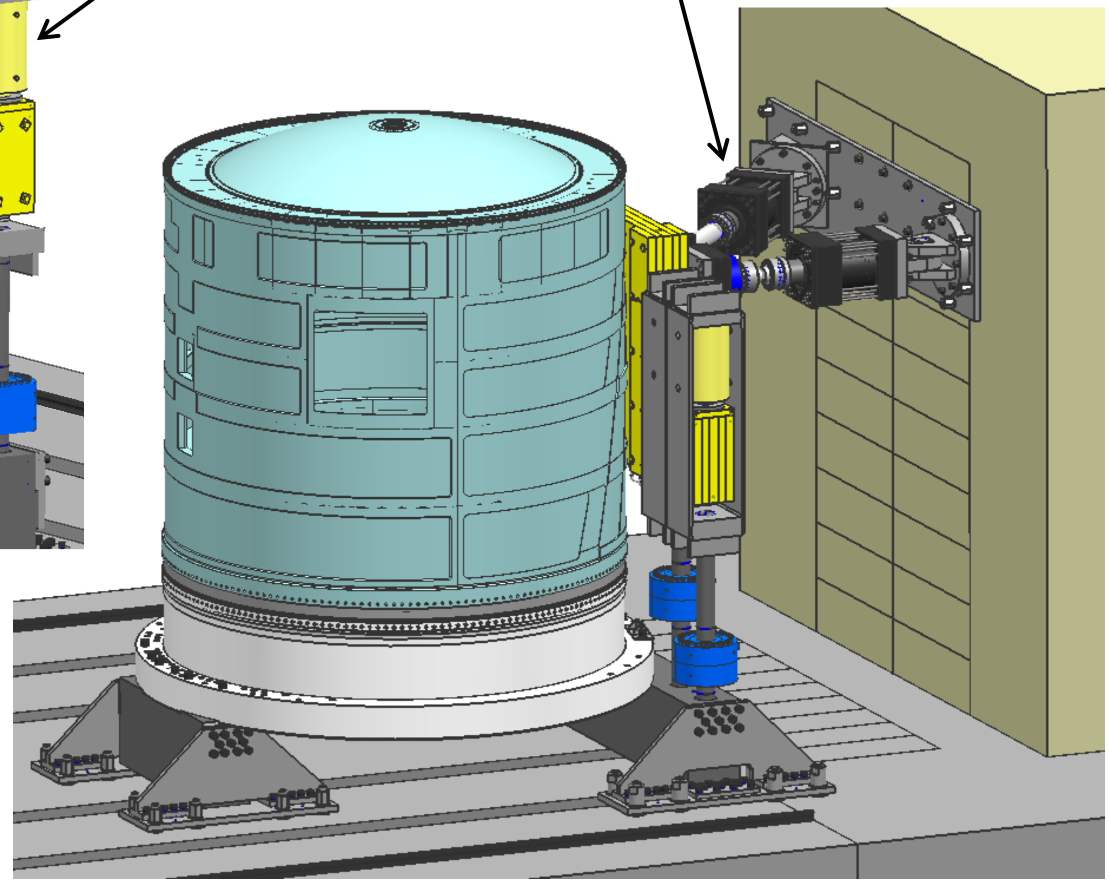
Forward Skirt Structural Test Article (FSTA)

- Testing was performed at Orbital ATK facilities in Promontory, Utah.
  - FSTA-1 was focused on ascent load cases
  - FSTA-2 was focused on liftoff load cases
  - Both tests applied ascent loads until failure occurred



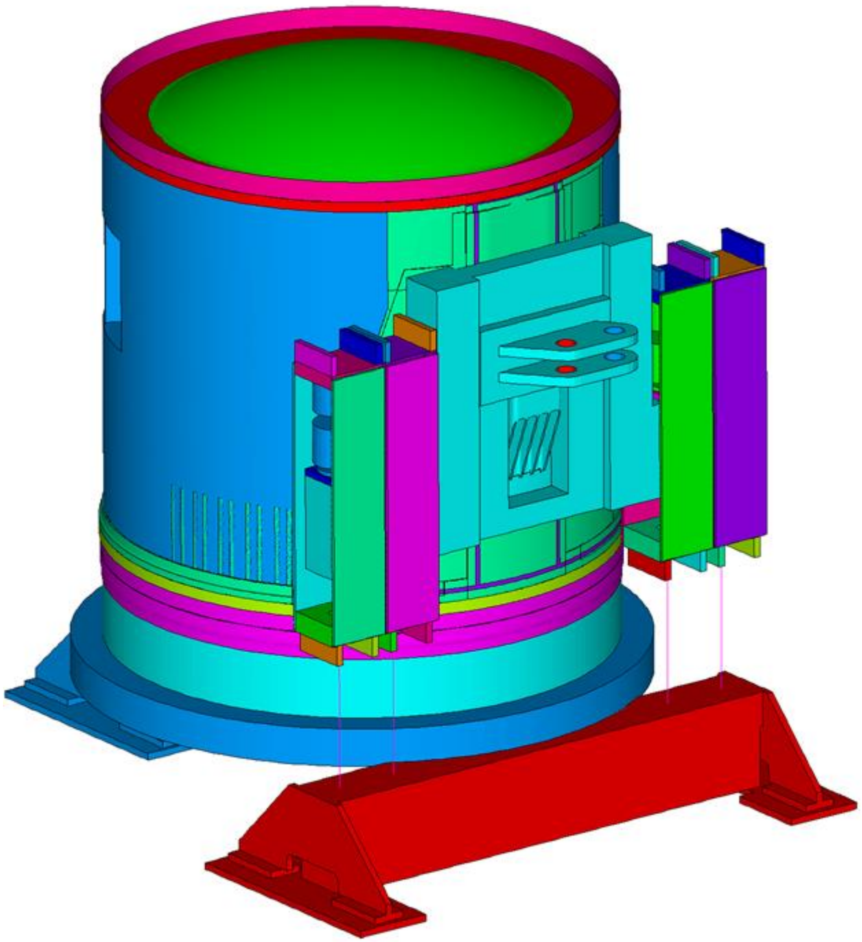
Test Article Description



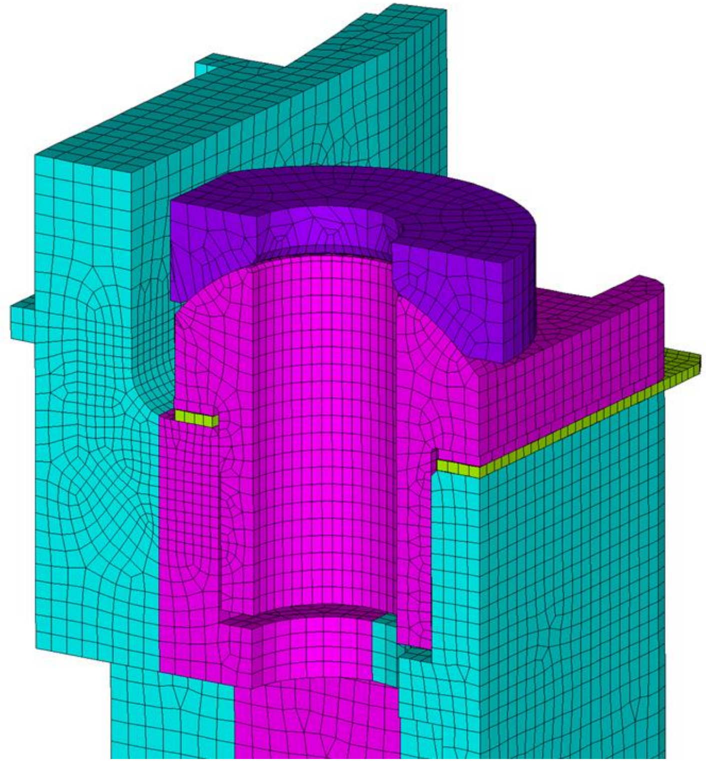


Finite Element Model

- Both the forward skirt and tooling was modeled. This allows the analysis to simulate the loading as close as possible to the actual test configuration.

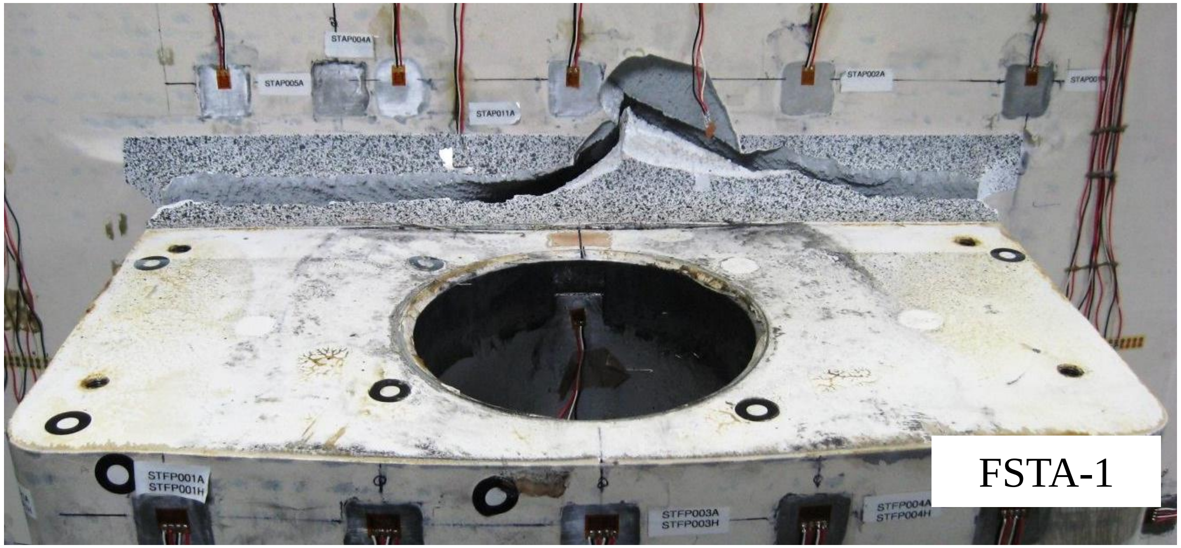


Mesh density in thrust post region



Test Results

- Failure occurred in the thrust post radius.
  - ➢ Both tests failed above 1.4 limit load
  - ➢ Testing alone was not sufficient to show forward skirts were acceptable



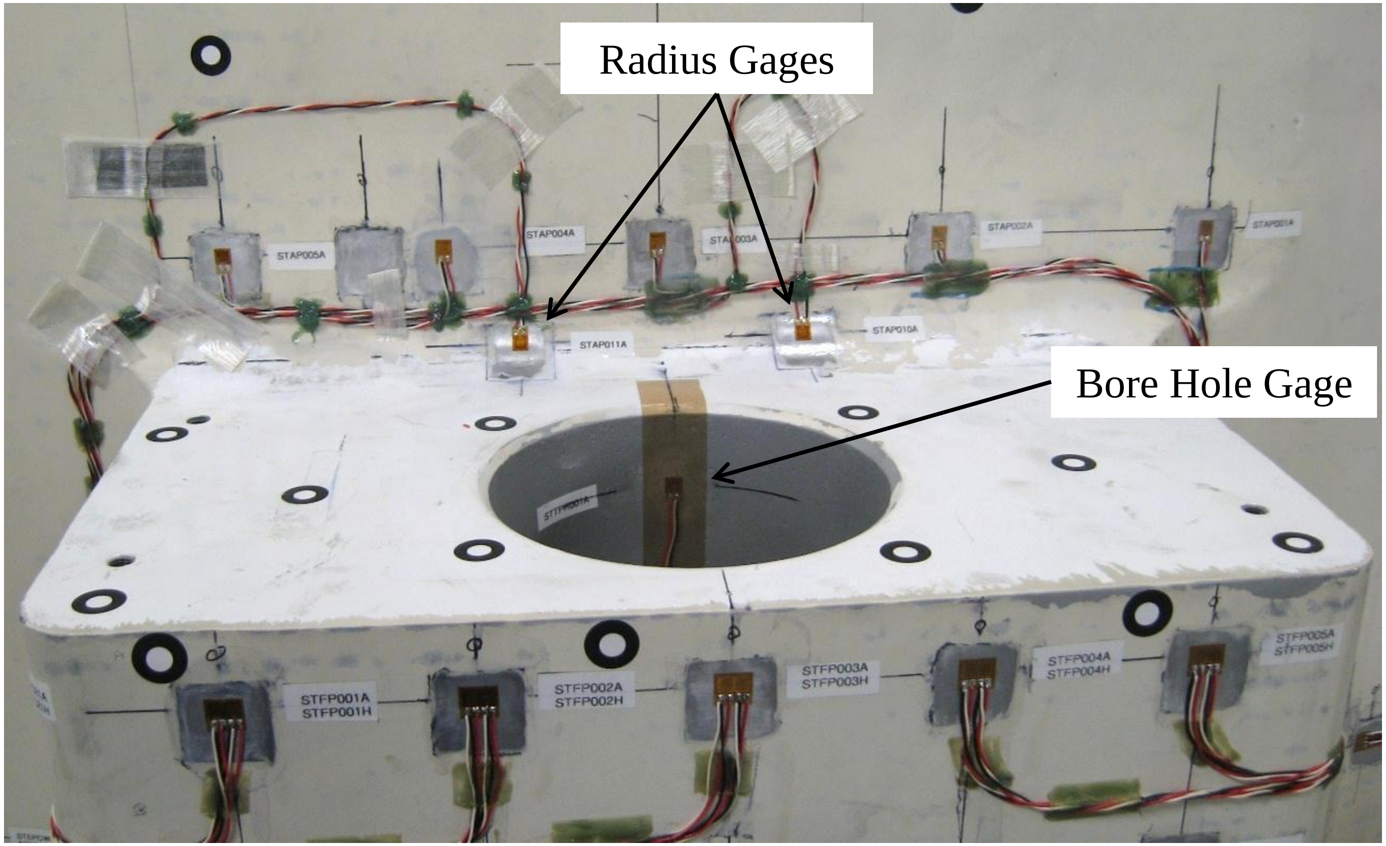
FSTA-1

- Still needed to understand the failure and correlate to analysis to determine a margin of safety.

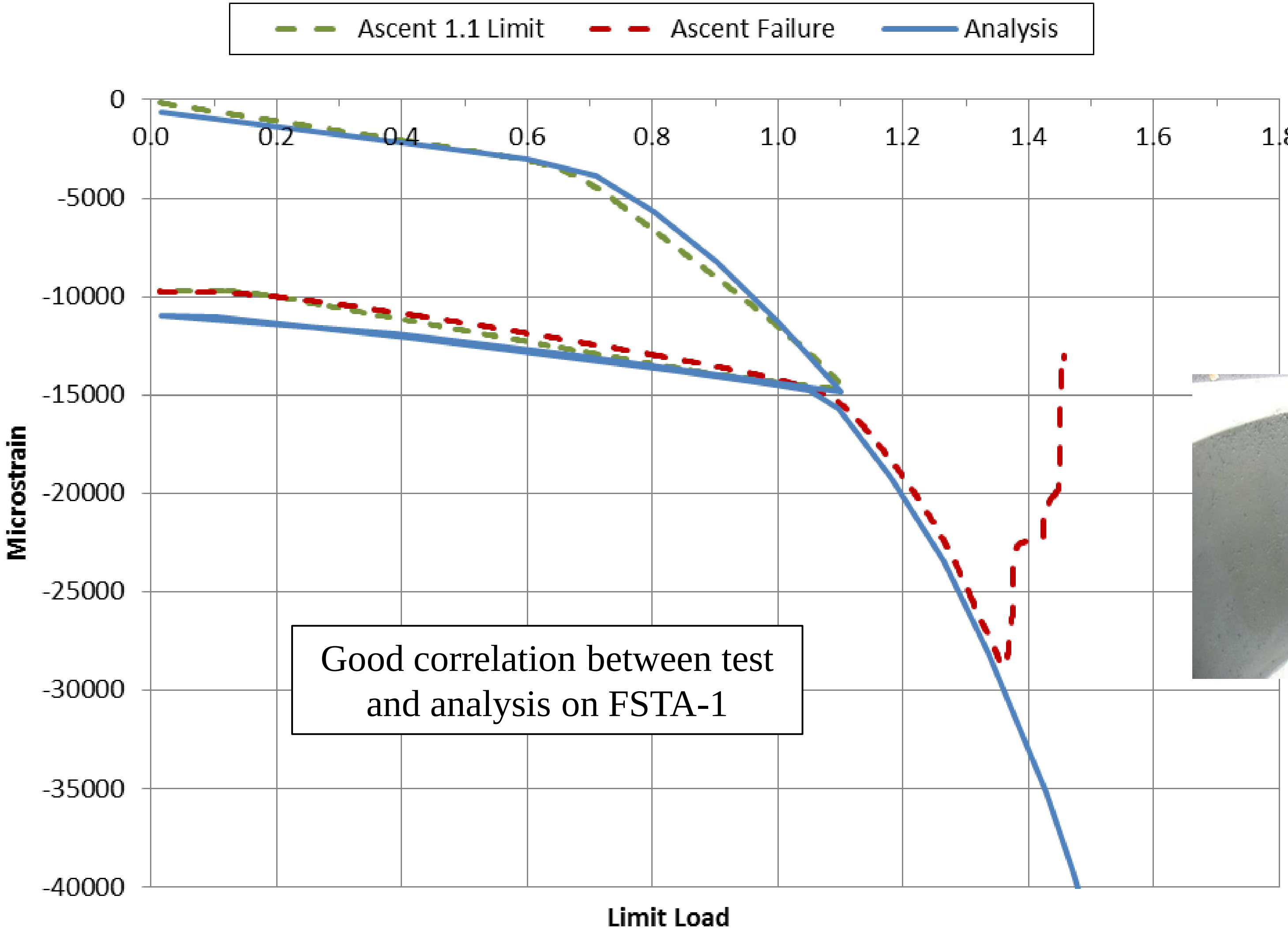
FSTA-2

Strain Gages

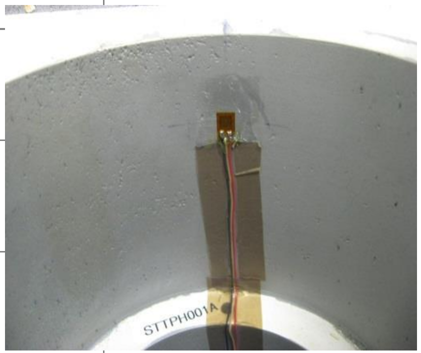
- FSTA-1 and FSTA-2 were instrumented with over 200 strain gages to ensure all possible failure modes could be captured.   However, it turned out that three gages provided the most useful strain data.



Strain Gage Results

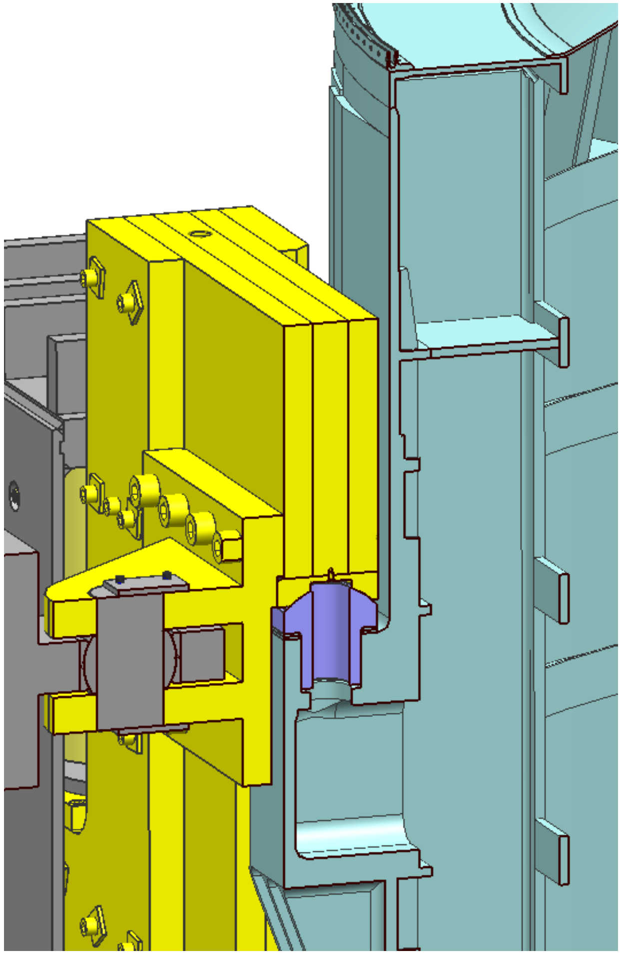


Good correlation between test and analysis on FSTA-1



Optical Strain Measurement

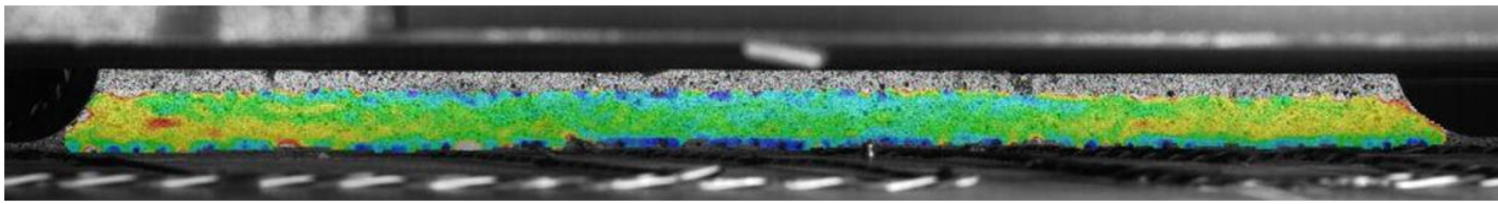
- Strain at the post radius was determined by processing digital images with the ARAMIS system.



Digital cameras location

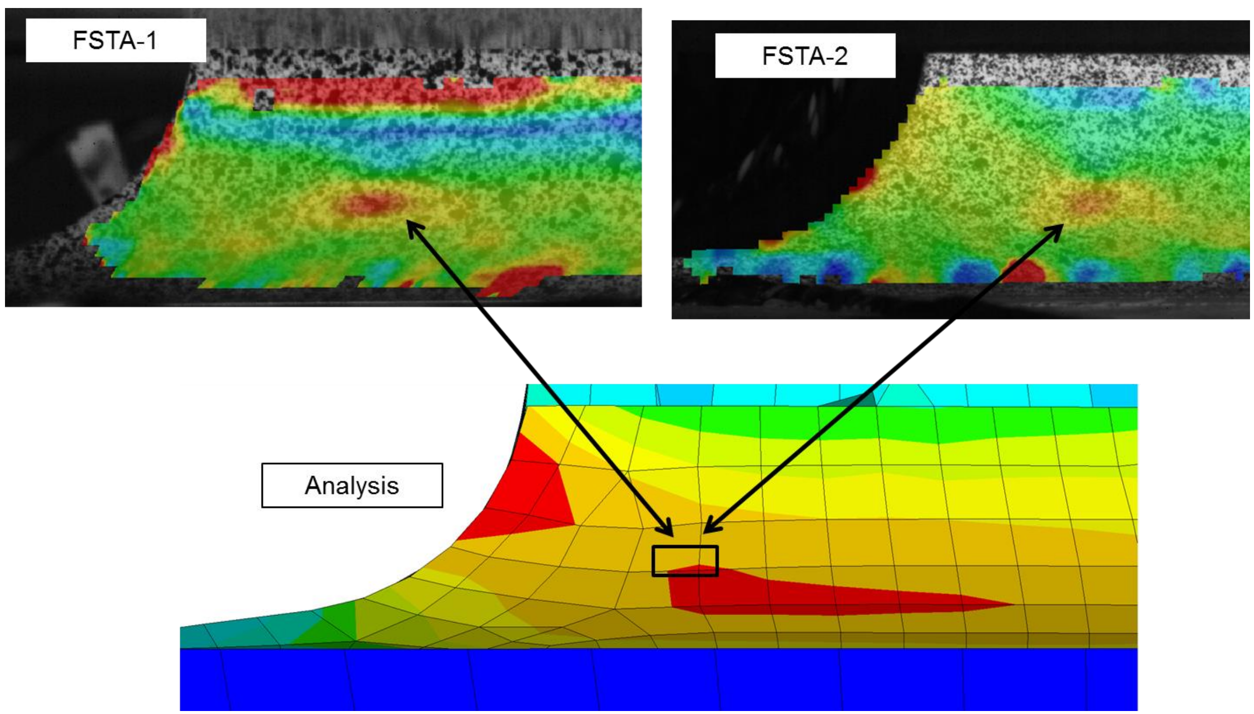
ARAMIS Strain Results

- ARAMIS was able to accurately capture the thrust post strain.   Correlation to analysis was excellent.



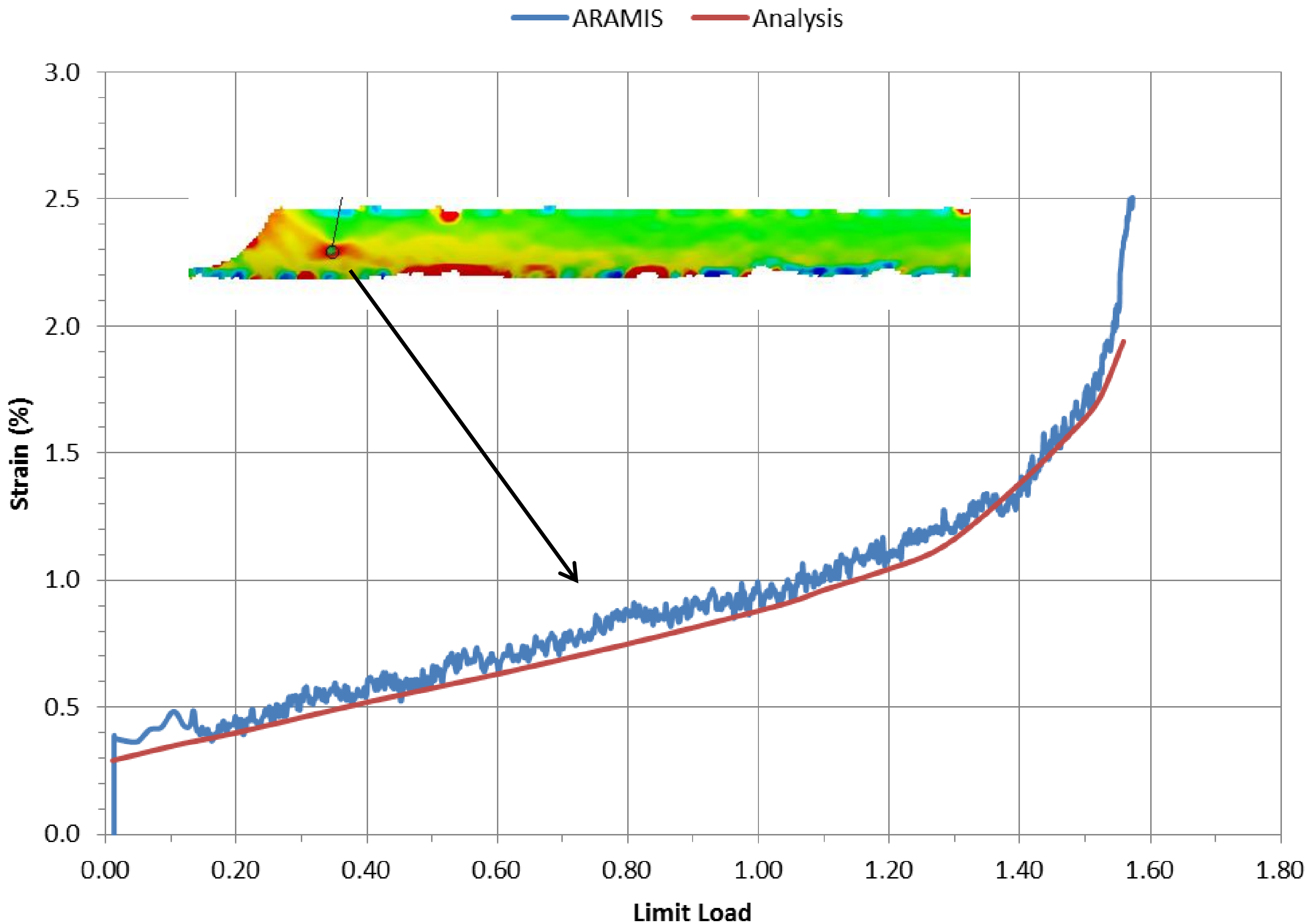
Strains just prior to failure

Hot spots match failure initiation sites



ARAMIS Strain Results

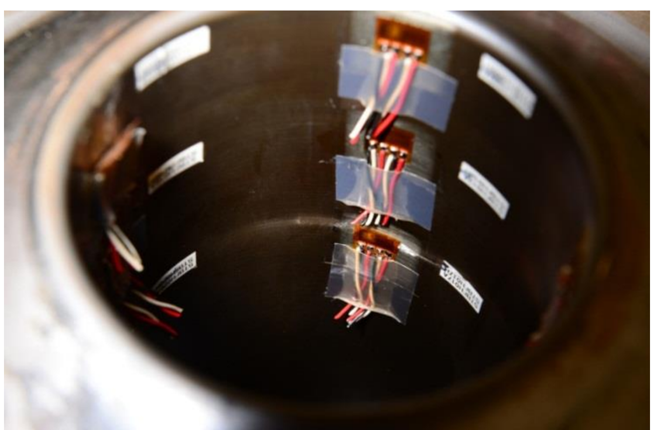
- ARAMIS allowed strain at hot spot to be plotted versus load. Correlation to analysis was excellent.

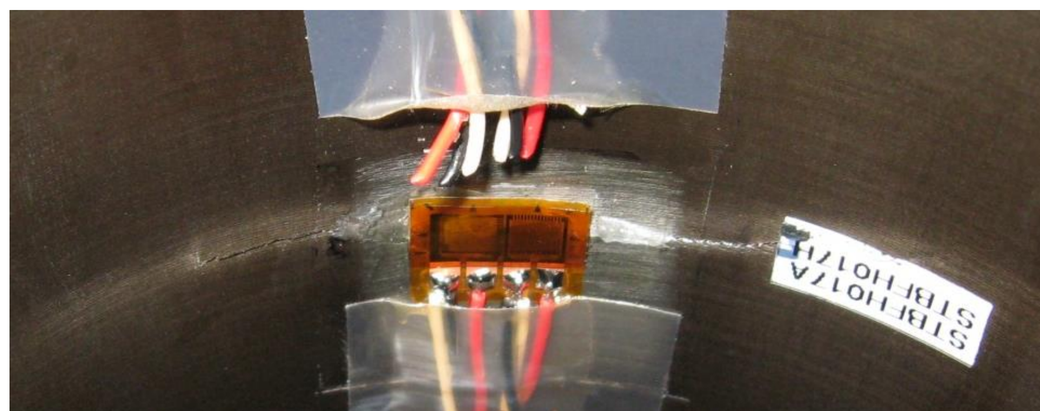


FSTA-2 strain versus analysis

Acoustic Emission

- Acoustic emission (AE) sensors were used to monitor for damage formation during testing (e.g. crack formation and growth). AE was important because after disassembly of FSTA-1 a crack was observed in the ball fitting radius.

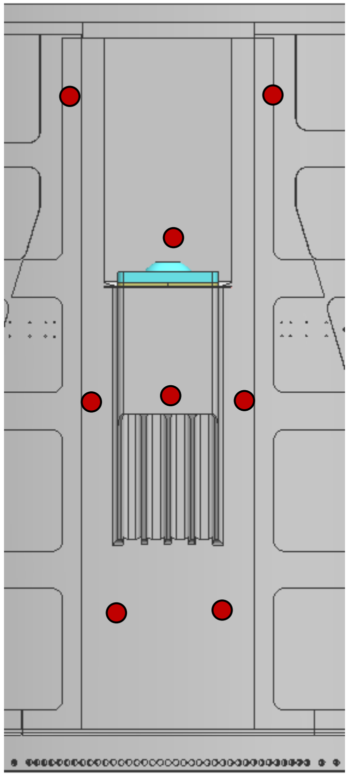


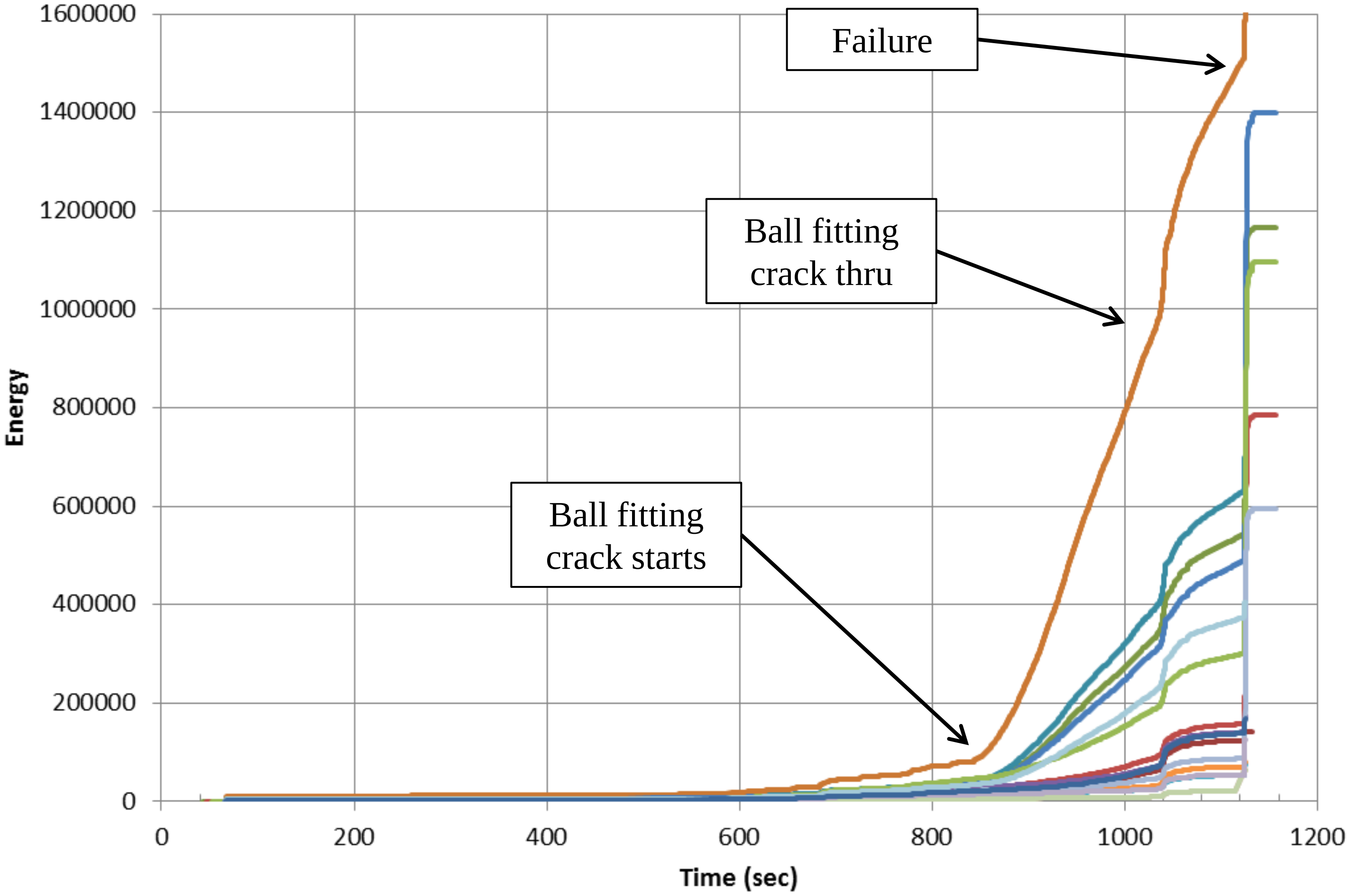


Acoustic Emission Data

- AE data was used to reconstruct when the crack occurred. This was essential in determining the ball fitting margin of safety.

AE gages





Summary

- Testing combined with analysis helped show the heritage forward skirts were acceptable to use on the SLS program.

- This saved the SLS program approximately 30 million dollars because new forward skirts did not need to be designed, tested, and manufactured.