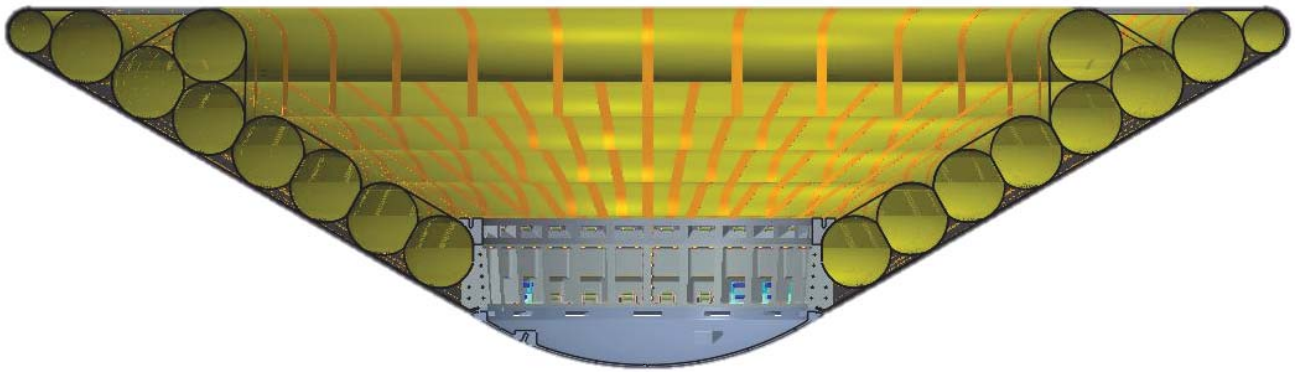
# Overview of the 6 meter HIAD Inflatable Structure and Flexible TPS Static Load Test Series



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# Presentation Outline

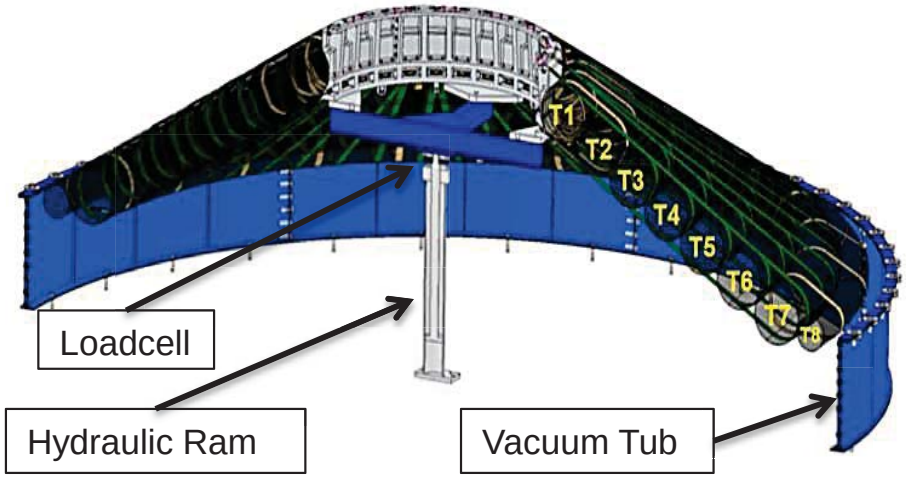
- Brief Overview of the HIAD Project
- Static Load Test Series Setup
- HIAD Test Article
- Test Instrumentation
- Test Execution
- Quick Look Results

# HIAD Overview

- NASA is investing in atmospheric entry technologies which can improve science and exploration capabilities
- Hypersonic Inflatable Aerodynamic Decelerators (HIADs) are one solution to lowering ballistic coefficient (by increasing drag area) without violating launch vehicle shroud constraints
- Decreasing ballistic coefficient can provide benefits in many key areas:
  - Peak heat flux and total integrated heat load
  - Payload mass
  - Landing site altitude
  - Deceleration
- Characterizing the structural response of HIADs under load is key to the understanding of their performance, development of future configurations, and validating and improving structural models
- Ground test campaign underway

# 6m HIAD Static Load Test Series

**Objective:** Validate that the inflatable structure w/TPS maintains its aerodynamic shape under flight-like loads without causing damage to the test article itself.



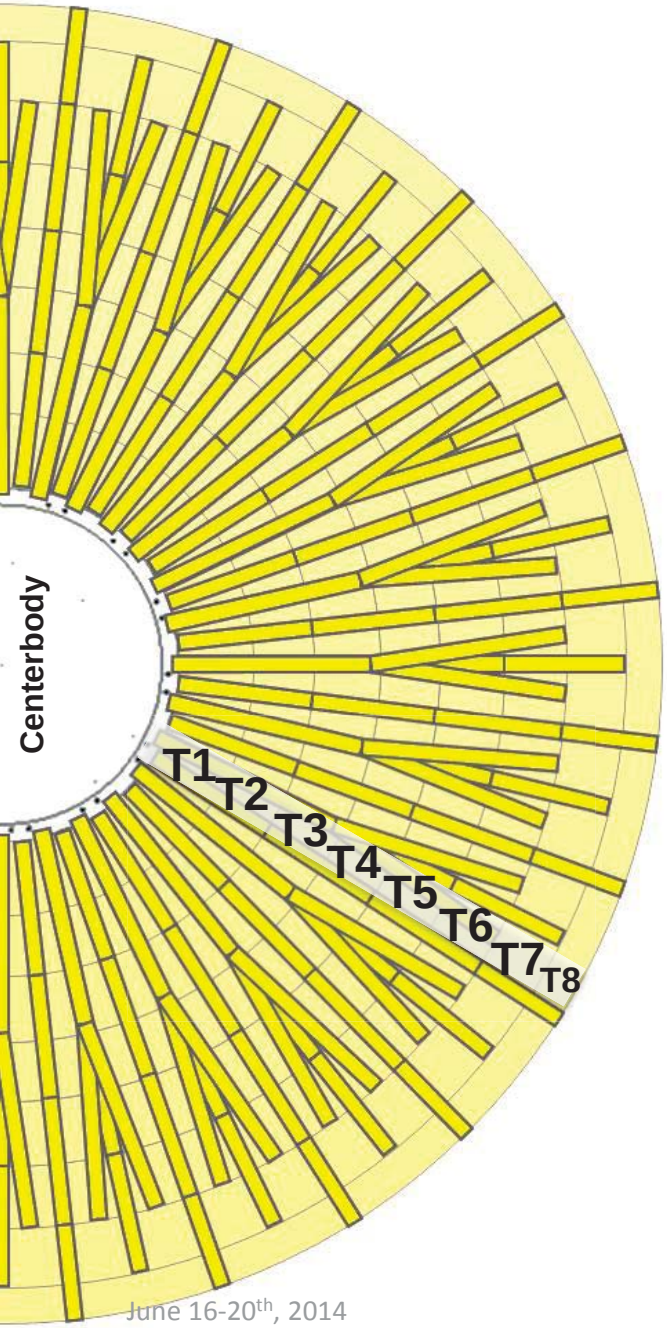

Static Load Test Setup

6m HIAD Inflatable Structure Before Testing

6m HIAD Inflatable Structure w/ TPS Before Testing

6m HIAD Inflatable Structure w/ TPS During Static Load Testing

# 6m Model Structural Strapping

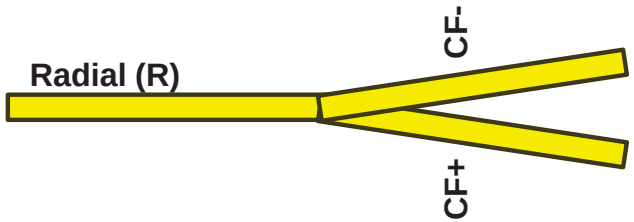



**Radial Straps:**
The radial straps (28 total) run from the centerbody on the forward side of the article and terminate as the anchor for the crow's feet straps.

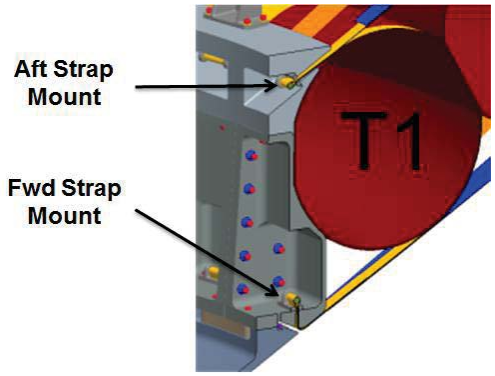
**Crow's-Feet Straps:**
Stitched to the radial strap around the T3/T4 valley on the forward side of the HIAD, the two crow's-feet straps wrap around the T6 to help transfer load from the should of the HIAD to the centerbody.

**Pairing Straps:**
Straps that secure two adjacent tori. They are staggered, in line with the radial straps, T2/T3, T4/T5, T6/T7 are paired, in between the radials T1/T2, T3/T4, T5/T6, T7/T8 are paired.

**Centerbody Attachment Straps:**
Secure T1 to the rigid centerbody. This strap, a continuation of the radial strap, is terminated at clevis pins on the forward and aft side of the article




**Crow's-Feet Straps**



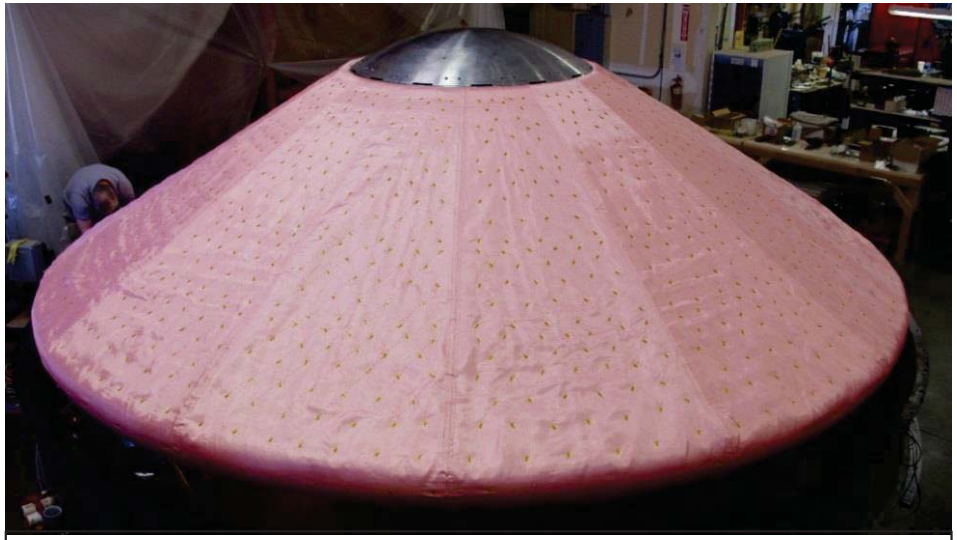

**Centerbody Attachment Straps**



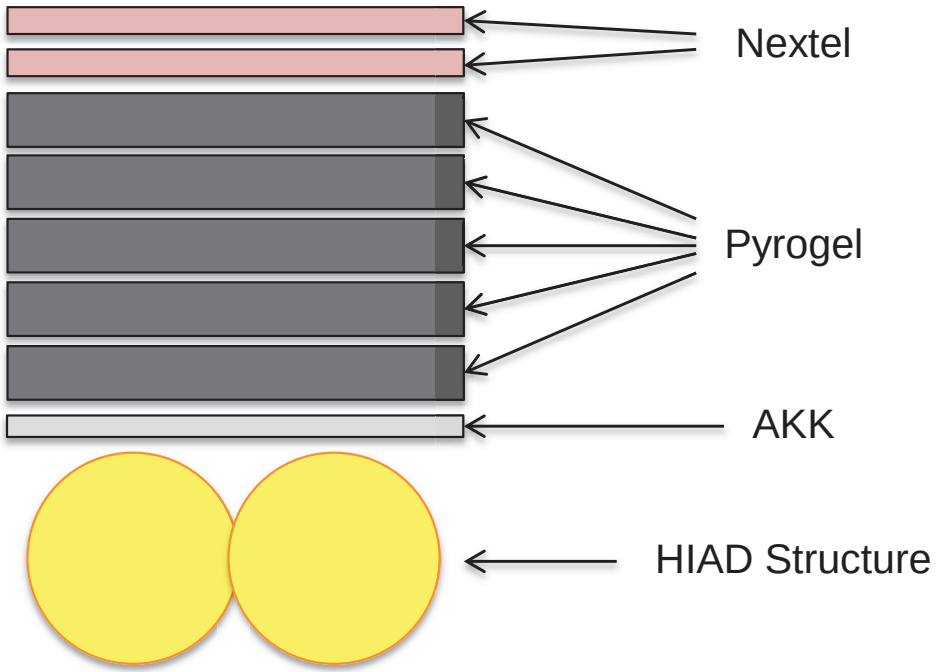
**6m HIAD Inflatable Structure**

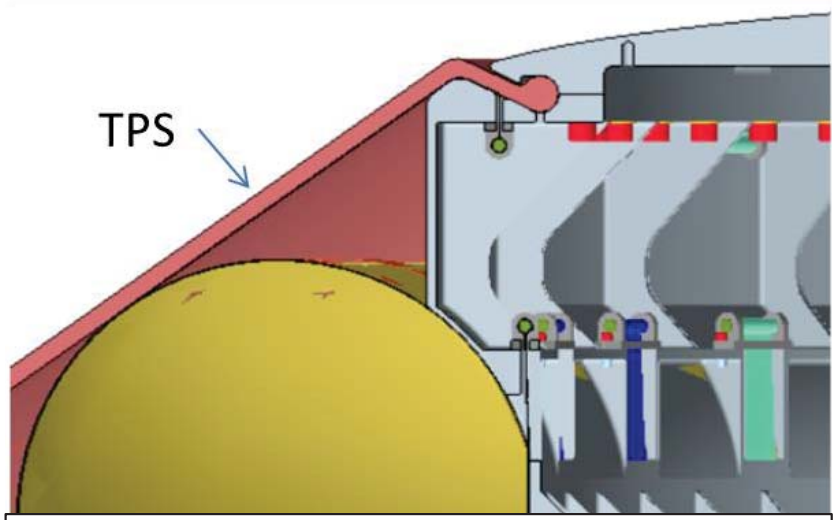
# 6m TPS Overview

- 6m TPS Fabricated by Jackson-Bond Engineering
- Two outer layers of Nextel
- Five Layers of Pyrogel for insulation
- One inner gas barrier layer of Aluminized Kapton-Kevlar



6m TPS Integrated on HIAD Inflatable Structure



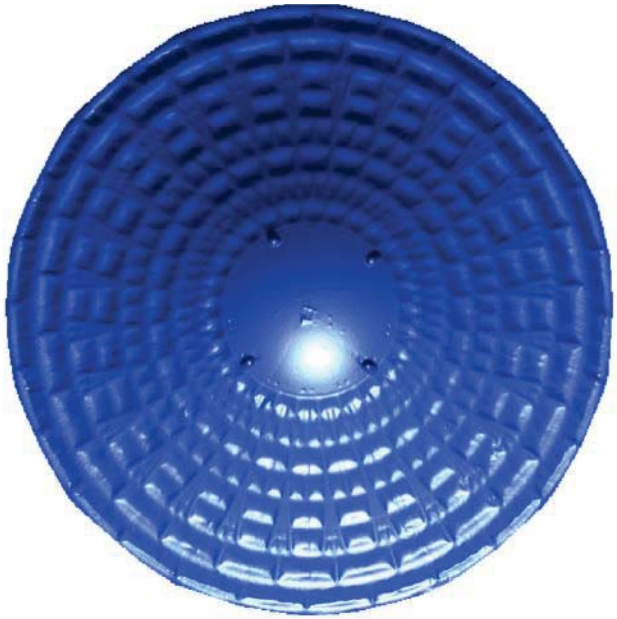

6m TPS Integration with Centerbody

# TPS Integration Video

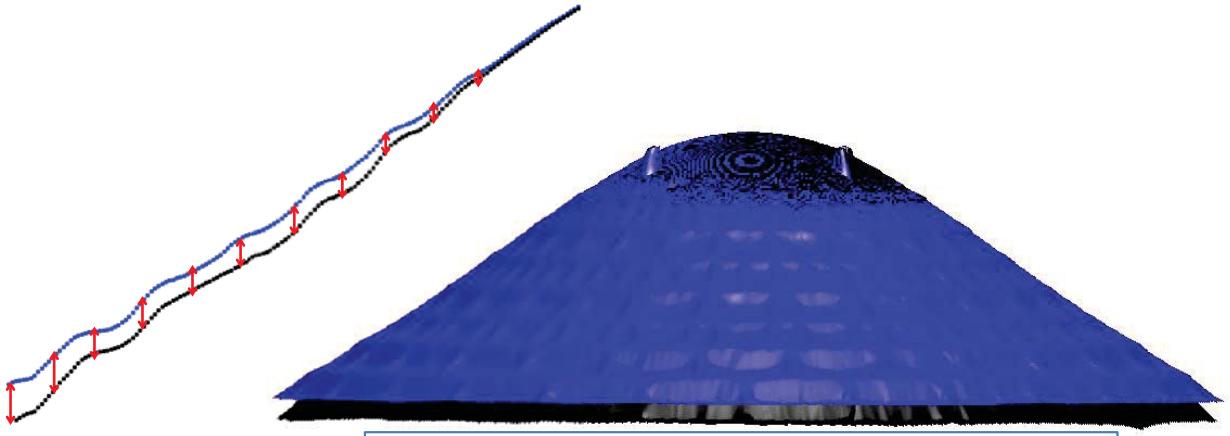
**Play TPS Integration Time-lapse Video**

# Instrumentation: Laser Scanner

- Laser scanning was used to inform the deflected shape of the HIAD structure under each static load condition.
- Scans were usually taken before loading, at ½ load, ¾ load, and full load.
- This data was then compared to view the performance of the structure given the different inflation settings.

Matlab Plots using 3D Point Cloud Files

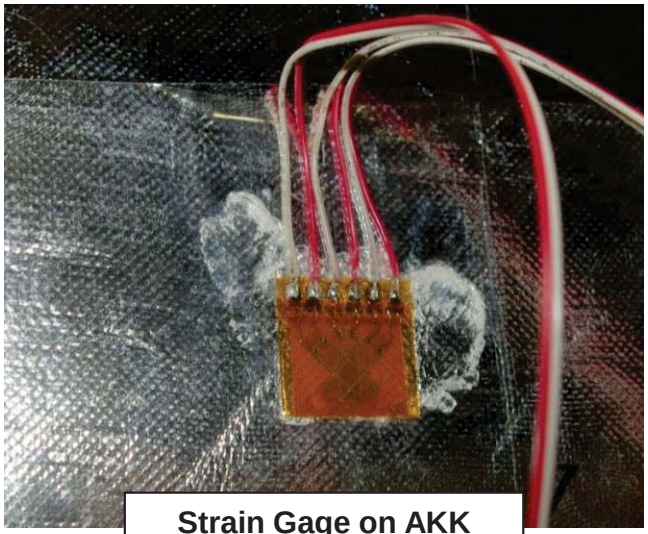


Deflection Comparison Between Two Loads

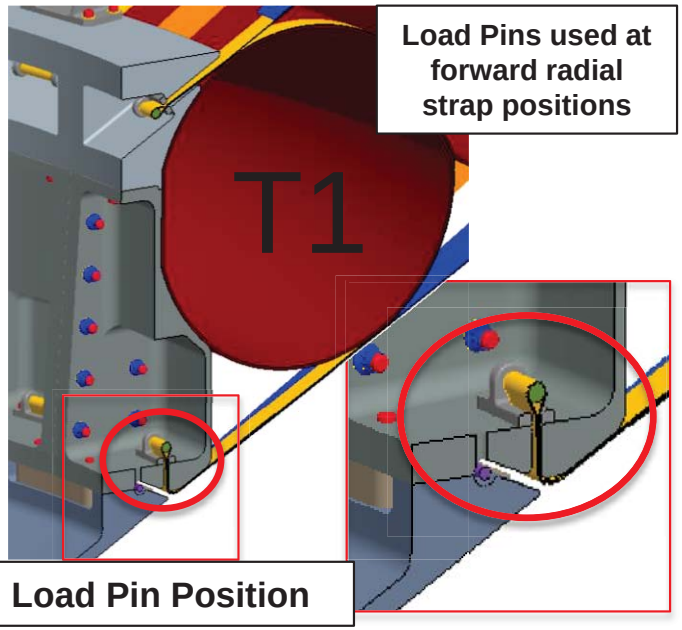
# Instrumentation: Loadcells, Strain Gages

Strap Load Pin


Strap Tension Gage

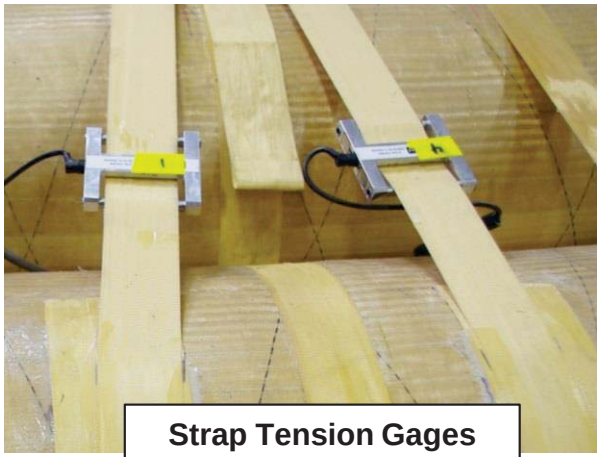


Strain Gage on AKK




Load Pins used at forward radial strap positions

Load Pin Position



Strap Tension Gages on Crow's Feet Straps

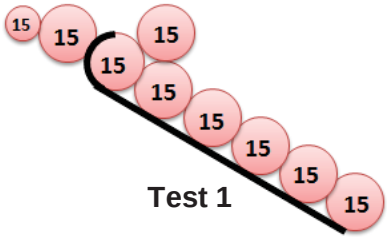
Strain Gage on Torus Cord

Also Used: String Pots, Manometer, Pressure Transducers, Ram Loadcell

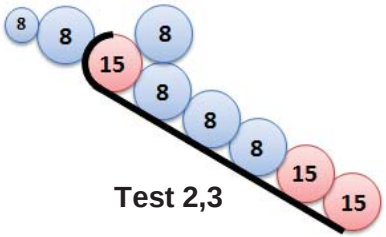
# Jan 2014 Static Load Test Overview

6m HIAD IS Tested Under Static Load in Two Configurations:

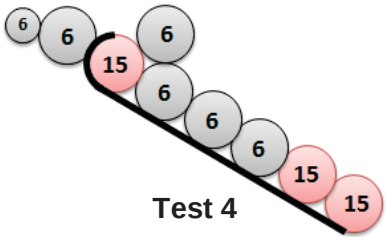
1. Without TPS
2. With TPS



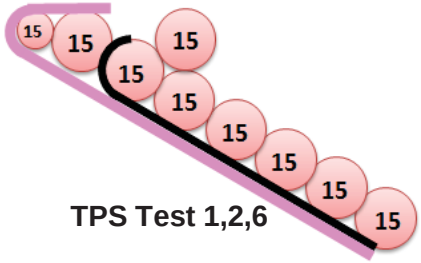
Test 1



Test 2,3



Test 4

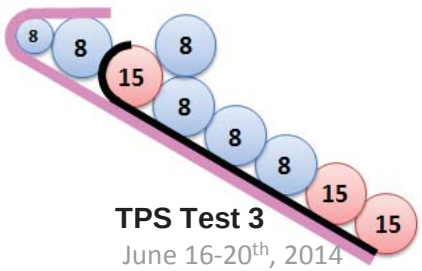


TPS Test 1,2,6

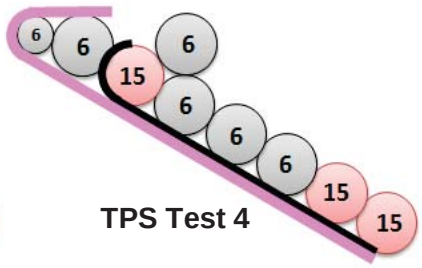
| No TPS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Test # | Torus Pressures | | | | | | | | | Load Cases | | | |
| | | | T1 | T2 | T3 | T4 | T5 | T5.5 | T6 | T7 | T8 | 10k | 20k | 30k | 40k | 50k |
| 1/10/2014 | | 0 | - | - | - | - | - | - | - | - | - | Inflation Ramp | | | | |
| 1/10/2014 | | 1 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | X | X | X | | |
| 1/10/2014 | | 2 | 15 | 15 | 8 | 8 | 8 | 8 | 15 | 8 | 8 | X | X | X | | |
| 1/10/2014 | | 3 | 15 | 15 | 8 | 8 | 8 | 8 | 15 | 8 | 8 | | | X | | |
| 1/10/2014 | | 4 | 15 | 15 | 6 | 6 | 6 | 6 | 15 | 6 | 6 | X | X | X | | |

| With TPS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Time | Test # | Torus Pressures | | | | | | | | | Load Cases | | | |
| | | | T1 | T2 | T3 | T4 | T5 | T5.5 | T6 | T7 | T8 | 10k | 20k | 30k | 40k | 50k |
| 1/14/2014 | | 0 | - | - | - | - | - | - | - | - | - | Inflation Ramp | | | | |
| 1/15/2014 | | 1 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | X | X | X | |
| 1/15/2014 | | 2 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | X | X | X | |
| 1/15/2014 | | 3 | 15 | 15 | 8 | 8 | 8 | 8 | 15 | 8 | 8 | | X | X | X | |
| 1/15/2014 | | 4 | 15 | 15 | 6 | 6 | 6 | 6 | 15 | 6 | 6 | | X | X | X | |
| 1/15/2014 | | 5 | 12 | 12 | 8 | 8 | 8 | 8 | 12 | 8 | 8 | | X | X | X | X |
| 1/15/2014 | | 6 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | X | X | X | X |
| 1/15/2014 | | 7 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | | X | X | X | X |
| 1/15/2014 | | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | X | X | X | |

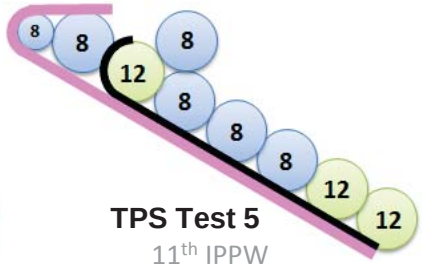
Each run started at no load, and then was increased to a specified load. That load was then held for 2-3 mins to allow the laser scanner to run. After the scan was complete the vacuum was increased to the next load. This process was repeated until the highest desired load was reached



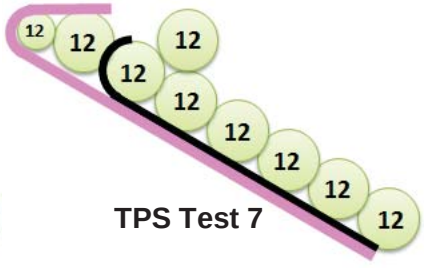
TPS Test 3



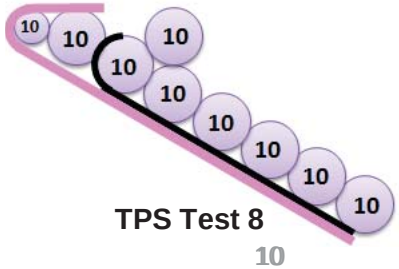
TPS Test 4



TPS Test 5



TPS Test 7



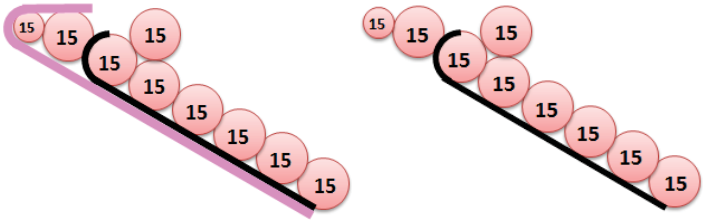
TPS Test 8

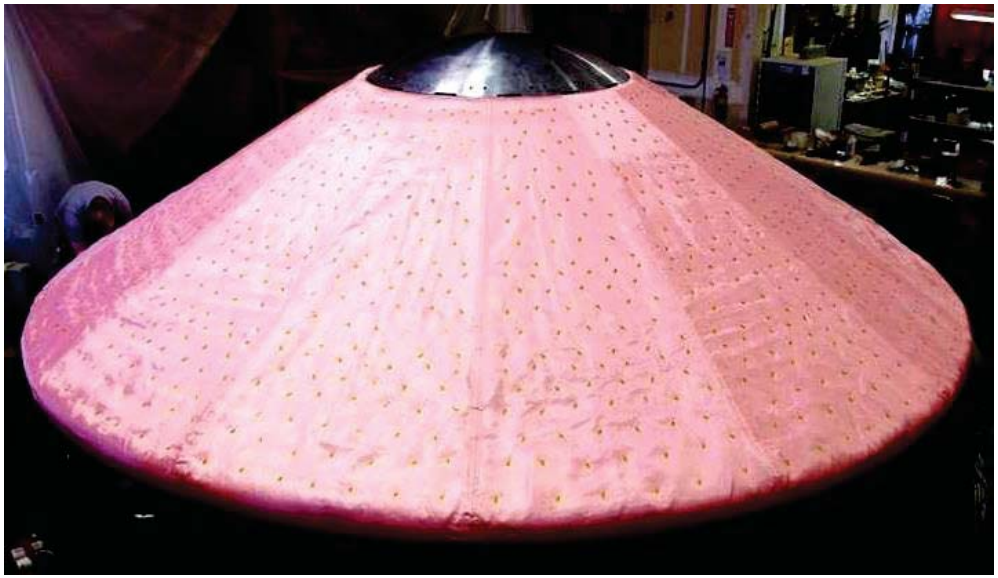
# Static Load Time-Lapse Video

**Play Run 6 Time-lapse Video**

# Results: Structure vs. Structure w/ TPS

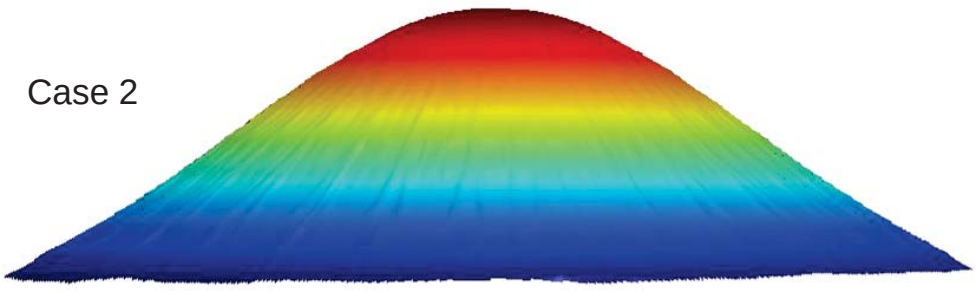
- As intended, the TPS carries a significant amount of the load at 15 PSI. This can be seen when comparing Run 1 (No TPS), and Run 2 (w/ TPS)
- Summing the loads into the centerbody (LP-R, LP-FT1, LP-AT1) indicates how much load is carried by the TPS (this of course does not include the contact load seen at the centerbody, or the loss of load due to the centerbody/strap friction in LP-R and LP-FT1).
  - At 20,000lbs the TPS carries: ~29% of the Load
  - At 30,000lbs the TPS carries: ~26% of the Load

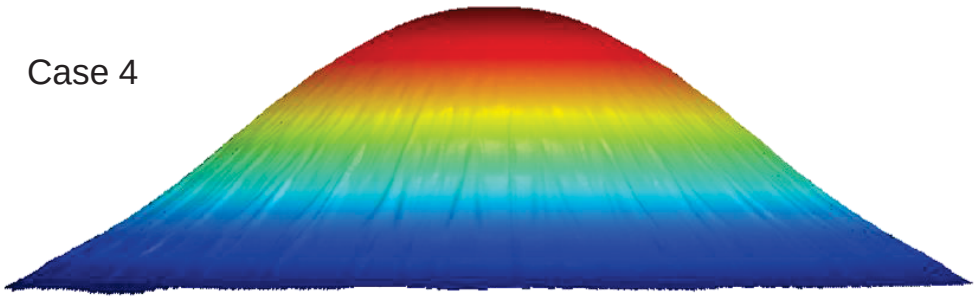


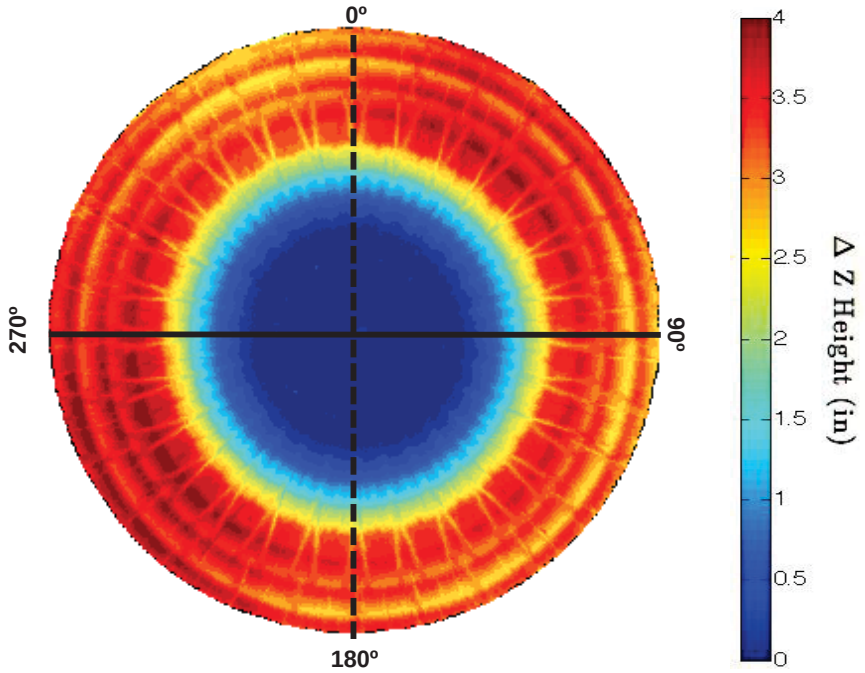
# Results: TPS Run 2 vs. 4 (40k lbs)

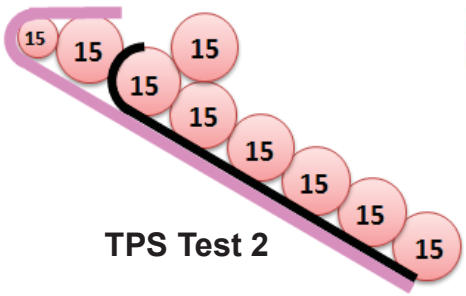
- Bell shape very pronounced with 15/6 psi inflation
- Case 4 exhibits increased deformation in the z-direction relative to case 2 $\mathcal{O}$(2-4%):
  - Constant at ~3 – 4” between T4-shoulder

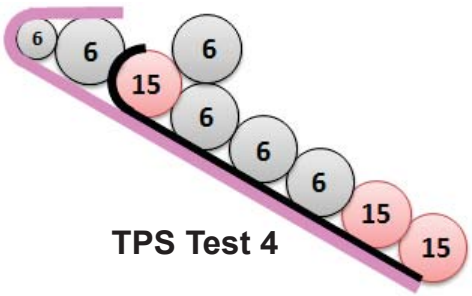


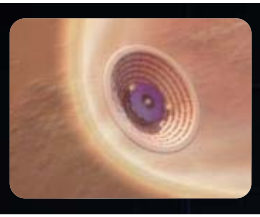







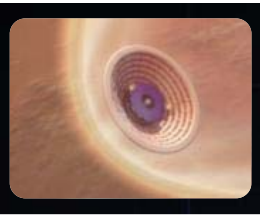





# Conclusion and Future Work

- The 6m HIAD inflatable structure with TPS performed admirably under loads up to 50,000lbs, at multiple inflation pressures.
- Test data has been delivered to the structural analysts to assist in refining their modeling efforts
- Package and deployment testing of the 6m HIAD w/TPS will be conducted this summer.
- The work from this 6m HIAD static load test series is being used to inform the design and fabrication of the next generation 3.7m HIAD article, which will utilize higher temperature capable materials for the structure.
- Once the 3.7m HIAD is complete a static load test, similar to the 6m HIAD test series, will be conducted.



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