Infusion of HIAD Structural Webbing for Low-Profile Load Measurement

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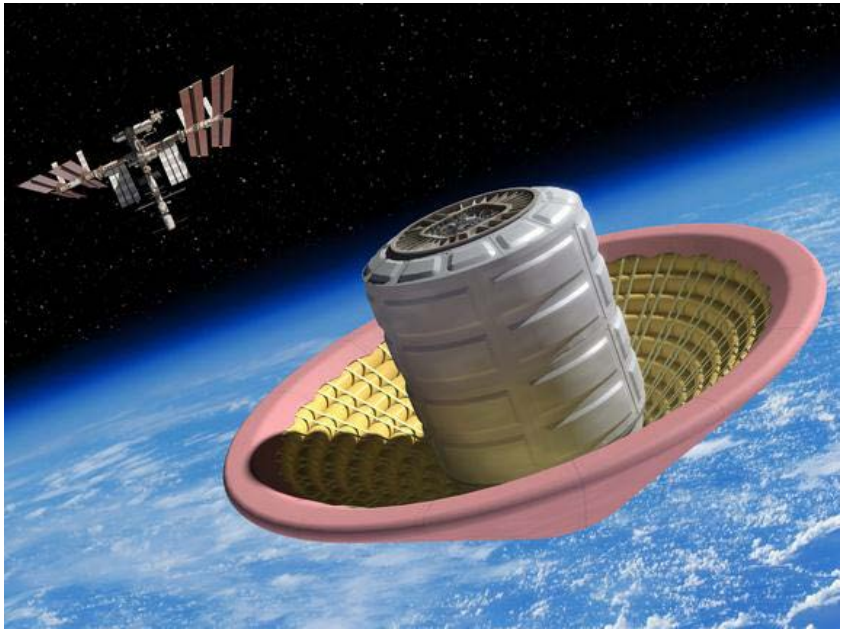
HIAD Overview

- 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 current launch vehicle shroud constraints.
- Low ballistic coefficient architectures can provide benefits in many key areas:
  - Increased payload mass fraction
  - Increased landing site altitude (Mars)
  - Lower deceleration loads
- 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.

Figure 1



HIAD Stack and Strap Configuration

Stacked Toroid HIAD Structure

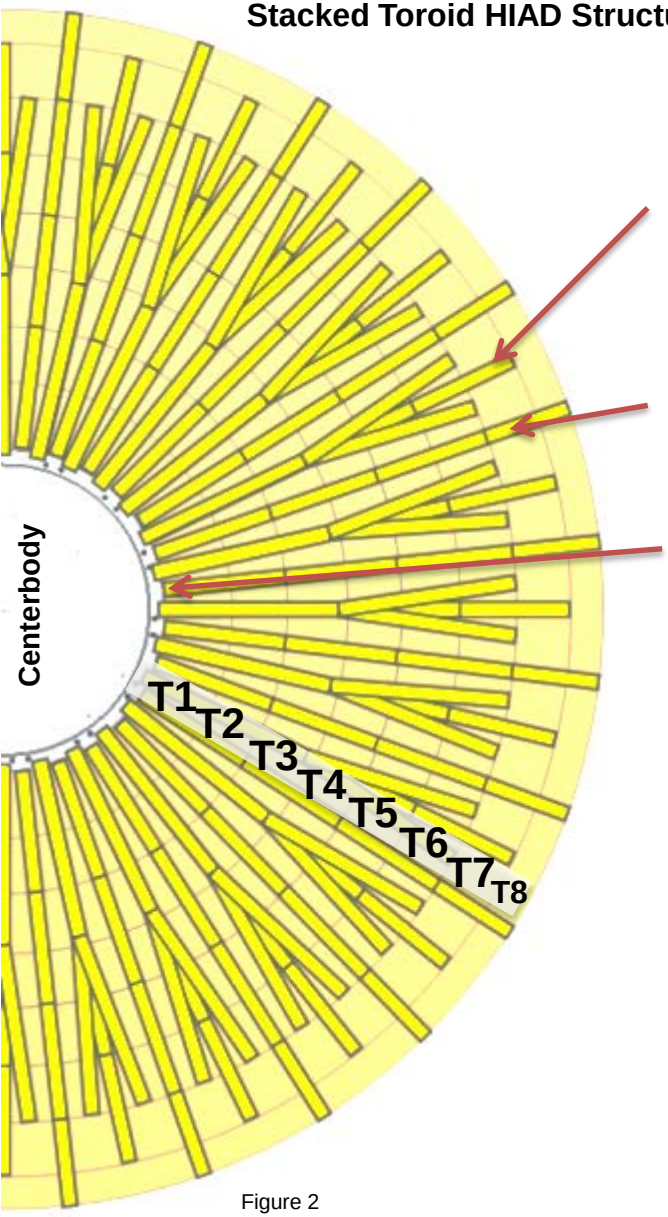


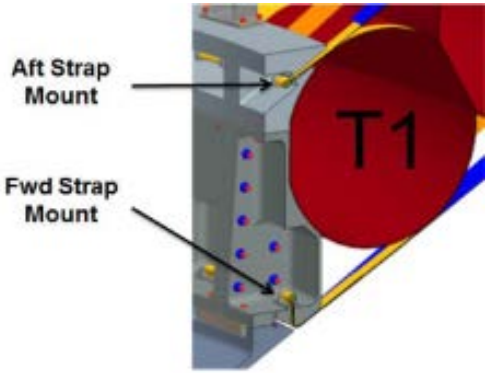
Figure 2

Radial Straps:
Radial straps run from the centerbody on the forward side of the article.

Pairing Straps:
Straps that secure two adjacent tori.

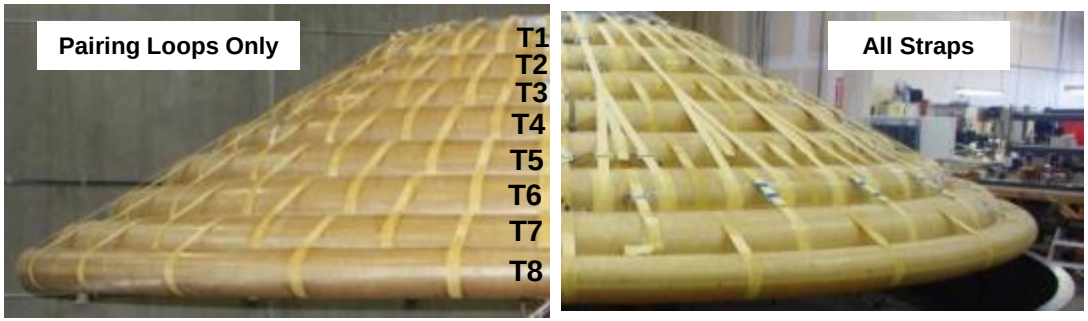
Centerbody Attachment Straps:
Secure T1 to the rigid centerbody.

Figure 3



Centerbody Attachment Straps

Figure 4



6 m HIAD Inflatable Structure

Premise for Strap Load Measurements

- Pairing strap load data is valuable for multiple reasons
  - Provide feedback for HIAD structural CAE model
  - Provide indication of overall HIAD loading and uniformity
    - Indicate indentation limitations of inflatable structure
  - Structural optimization
    - Strap efficiency, strength, location, and quantity required
    - Optimize torus inflation pressure

Figure 5

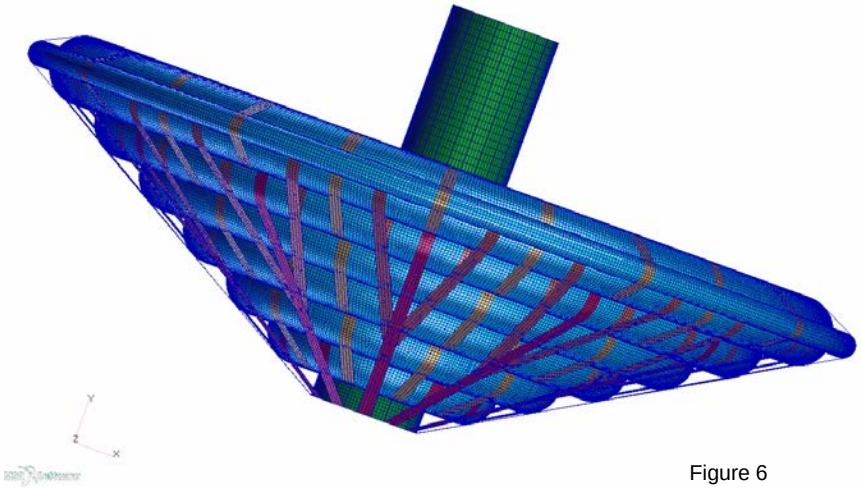


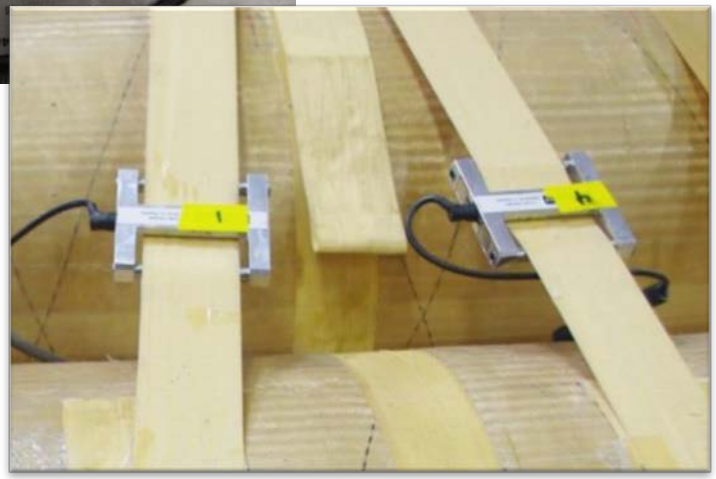
Figure 6

Current Load Measurement Instrumentation

- Strap Load Cells
  - Tensile loading in straps generates physical deformation to load cell which is calibrated to pairing strap load.
  - Excellent for ground testing, but pose mass and volume challenges for flight application
  - Also pose risk to inflatable structure during packing and stowage
    - Similarly can pose risk to damaging conformal TPS during packing and stowage

Figure 7

Figure 8



Flight Instrumentation Design Challenges

- Robustness
  - HIAD aeroshells are packed in extremely dense volumes for flight.
  - Instrumentation must be capable of withstanding packing stresses.
- Repeatability
  - Instrumentation needs to provide a repeatable response for a variable strap load.
- Thermal Effects
  - Because the current HIAD inflatable structure is capable to 400 C, the installed instrumentation system must be able to withstand similar temperatures, either by design or insulation (temperature can vary greatly depending on instrumentation placement)

Figure 9

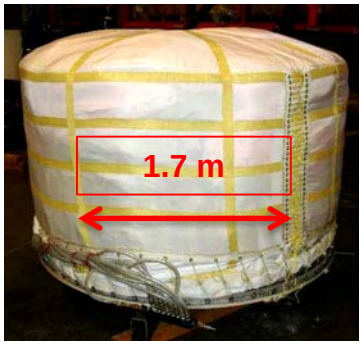


Figure 10

Lightly Packed 6 m (Note ref. dimension)

Possible Solution – Strain Gages

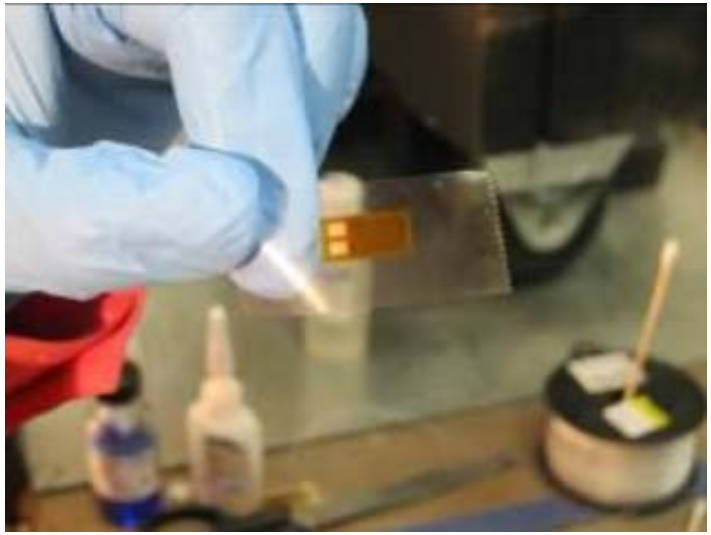


Figure 11

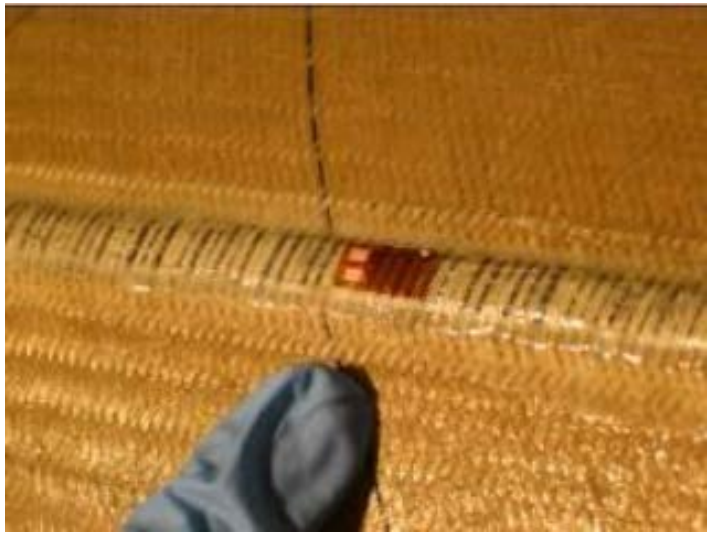


Figure 12

- Strain gages minimize weight and size of load measurement equipment (Figure 11).
- Simple and proven approach for reliable measurements
- Allow for the generation of calibration curves to indicate applied strap load relative to measured strains
- Challenges do exist with bonding strain gages directly to woven fabric (Figure 12) due to textile properties.
  - Inconsistent parent material
    - Unpredictable strain readings
    - Poor heat dissipation / induced thermal strains
    - Delamination

Localized Composite Concept

- ***Concept:*** Infuse epoxy into pairing strap material through pressure application procedure to provide rigid, robust mating surface for strain gage (Figure 13).
- RTV-560 buffer regions included to help prevent rigid epoxy edges from puncturing torus
- Fibre Glast® System 2000 Epoxy
  - First order reinforcement selection for proof of concept
- First prototypes
  - Kevlar
  - Unloaded manufacturing
- Later prototypes
  - Vacuum bagging
  - Preloaded manufacturing

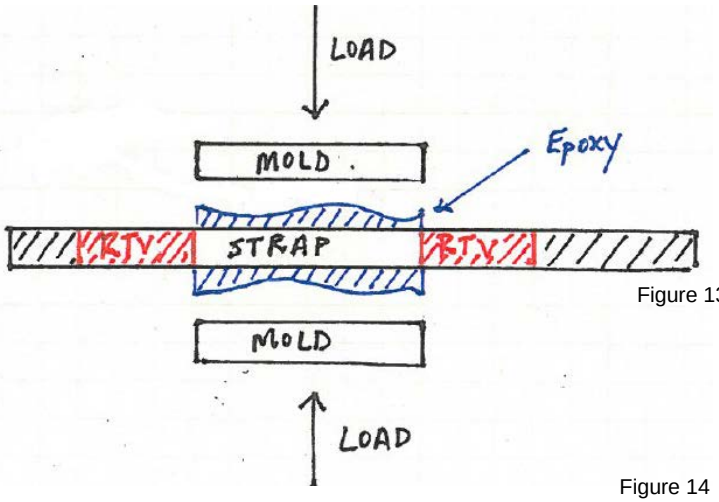
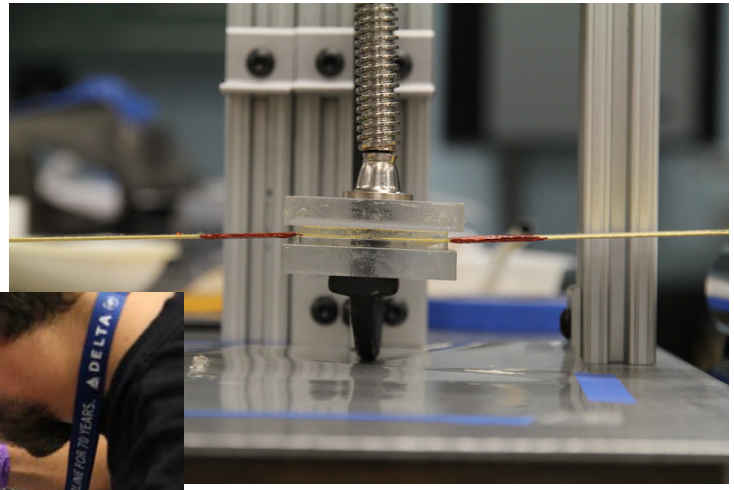


Figure 13

Figure 14



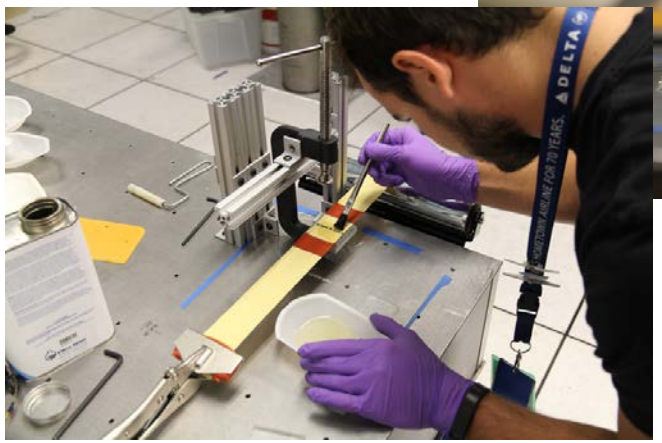


Figure 15

Prototype Testing

- Examine applied load to fabric strap relative to strain readings from strain gages (Figure 16).
- Generate load/displacement curves to validate structural robustness of composite material.
- Conduct multiple tests on multiple samples to indicate repeatability of composite prototype and instrumentation.
- If successful, alter process to push testing limits and parameters.
  - Max loading, loading rate, max cycles, hold time, etc.

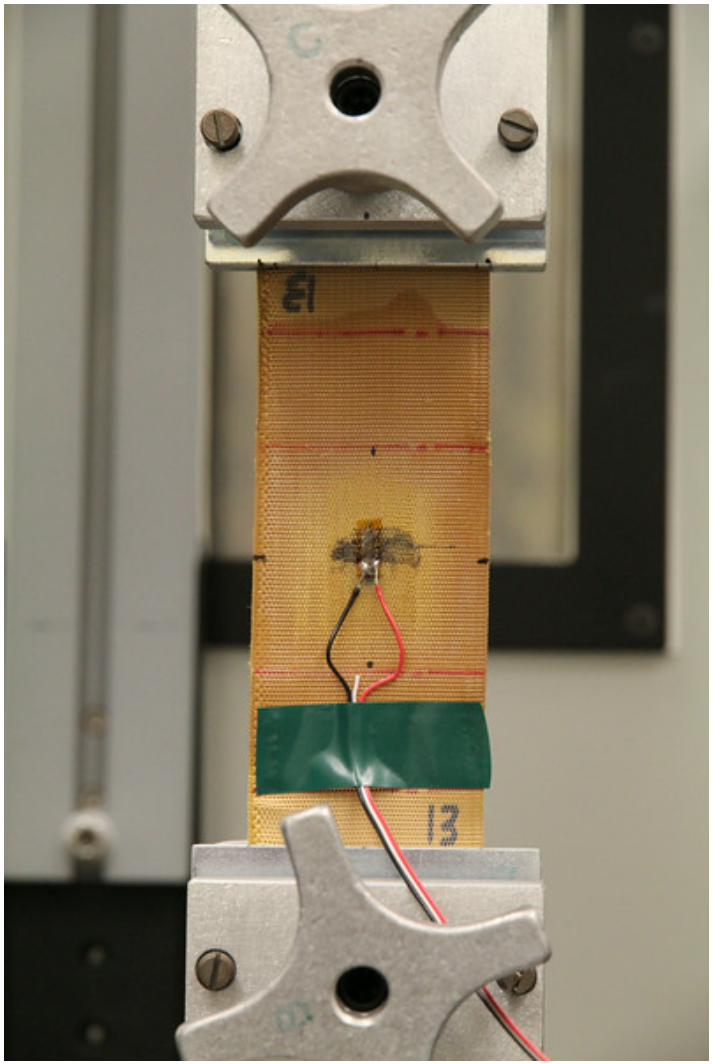
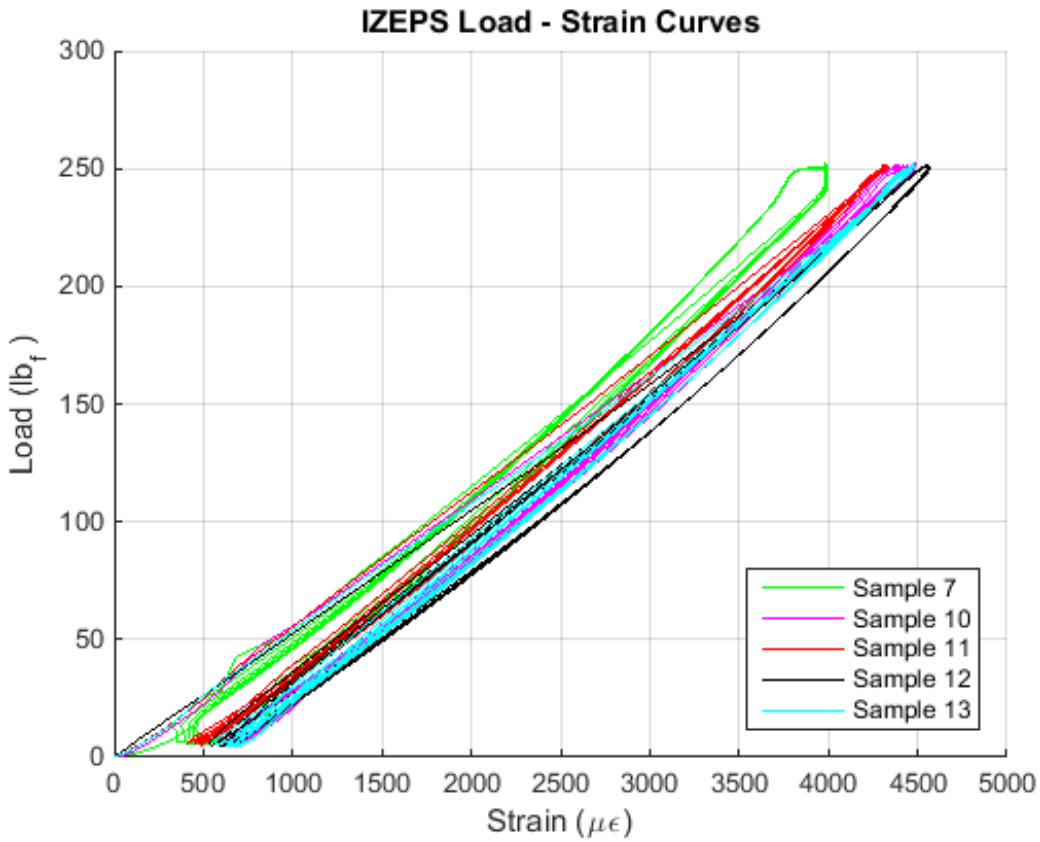
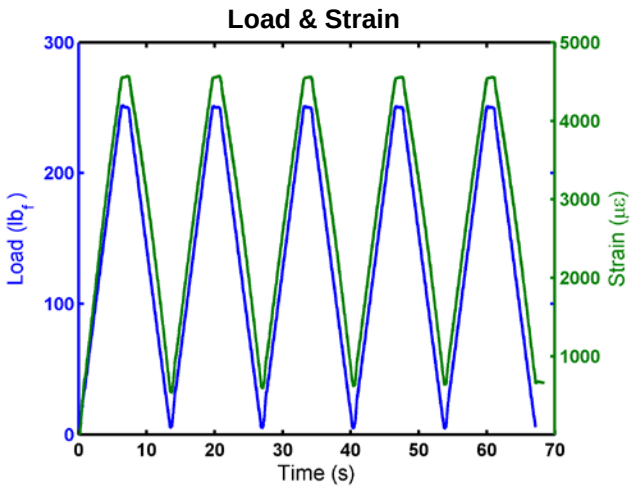
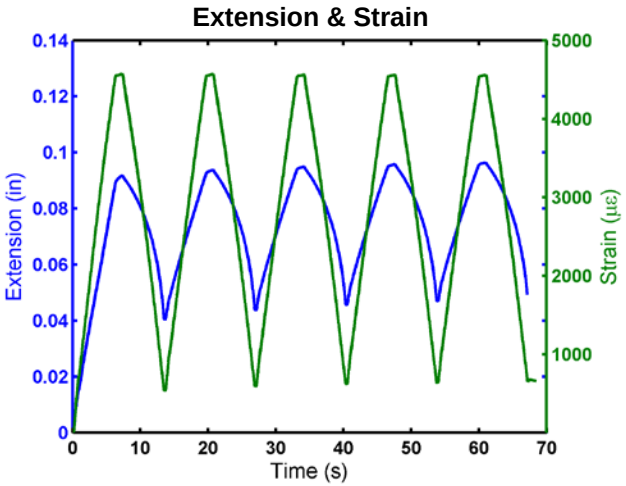


Figure 16

Test Results (Load / Strain / Extension)







- Load / Strain curves trend linearly
  - Indicates capability of instrumentation to withstand prescribed cyclic load without delaminating
  - More clearly seen when plotted temporally
- Significant improvement from nonlinear textile extension

Conclusions & Ongoing Research

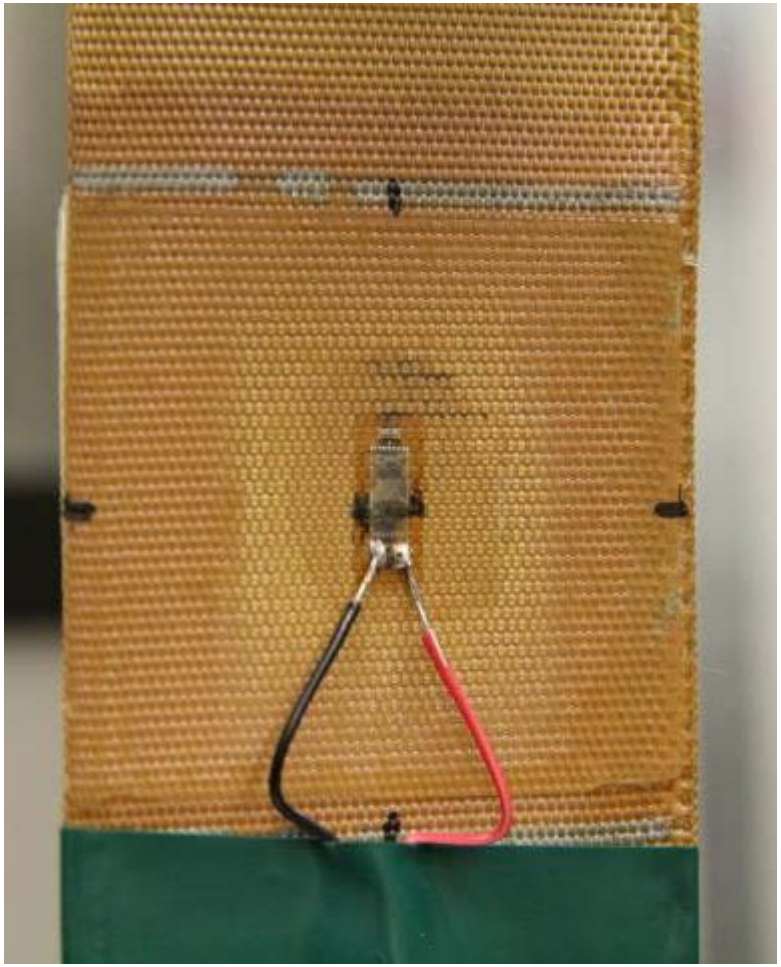


Figure 17

- Concept shows potential to satisfy initial problem; however, further experimentation with composite vacuum bagging and other manufacturing practices could prove beneficial.
  - More uniform localized composite
  - Optimization of fiber-resin ratio
  - Tailored production to work in parallel with HIAD fabrication.
  - Uniform pressure to all samples
- Preload straps prior to infusion to remove crimp in fabric
  - Minimize hysteresis and internal strains
- Configuration needs to be tailored for heating at predicted flight conditions.
  - (Epoxy, urethane, strain gage, adhesive catalyst, etc.)

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