INSTRUMENTATION DEVELOPMENT FOR LARGE SCALE HYPERSONIC INFLATABLE AERODYNAMIC DECELERATOR CHARACTERIZATION

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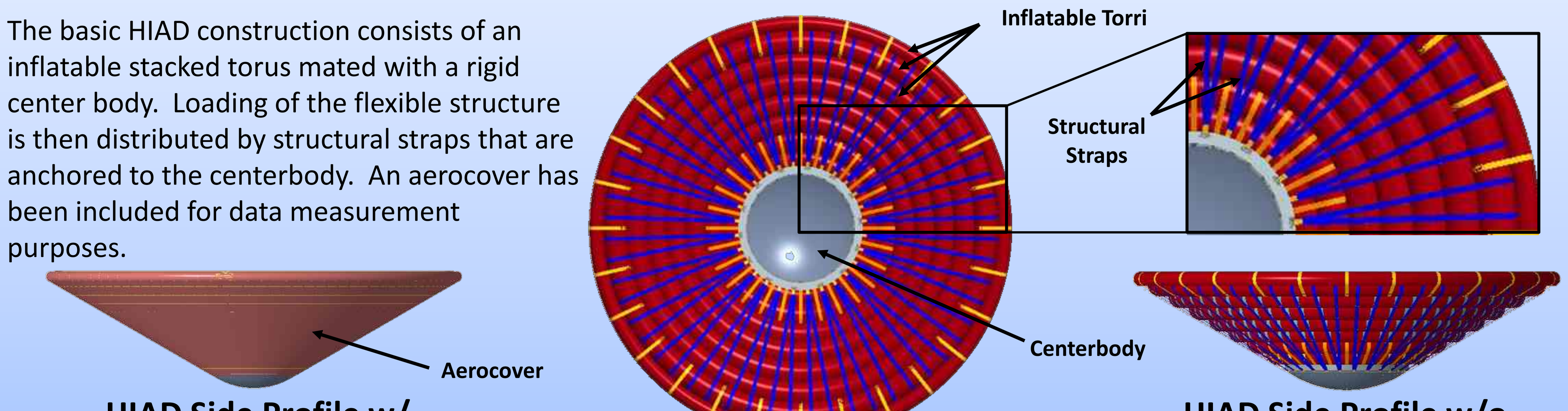
Background

Hypersonic Inflatable Aerodynamic Decelerator (HIAD) technology is currently being considered for multiple atmospheric entry applications as the limitations of traditional entry vehicles have been reached. The Inflatable Re-entry Vehicle Experiment (IRVE) has successfully demonstrated this technology as a viable candidate with a 3.0 m diameter vehicle sub-orbital flight. To further this technology, large scale HIADs (6.0 – 8.5 m) must be developed and tested. To characterize the performance of large scale HIAD technology new instrumentation concepts must be developed to accommodate the flexible nature inflatable aeroshell. Many of the concepts that are under consideration for the HIAD FY12 subsonic wind tunnel test series are discussed below.

HIAD Construction Overview

The basic HIAD construction consists of an inflatable stacked torus mated with a rigid center body. Loading of the flexible structure is then distributed by structural straps that are anchored to the centerbody. An aerocover has been included for data measurement purposes.



HIAD Side Profile w/ Aerocover | HIAD Head On Profile w/o Aerocover | HIAD Side Profile w/o Aerocover

Flexible Aeroshell Deformation

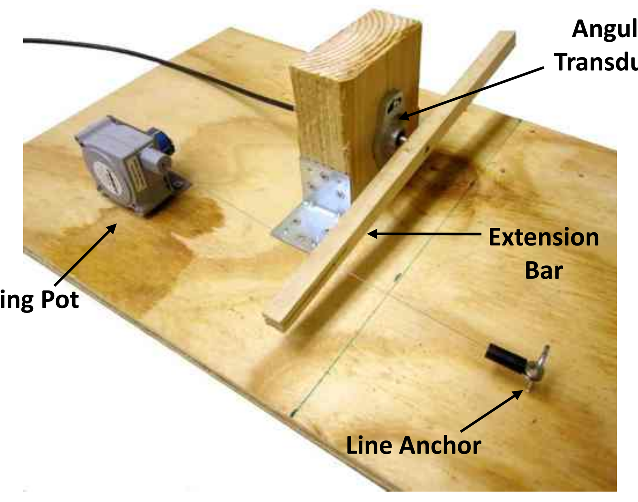
String Potentiometers and Angular Transducers

String pots teamed with angular transducers will provide 2D point tracking on the HIAD model indicating aeroshell deformation.

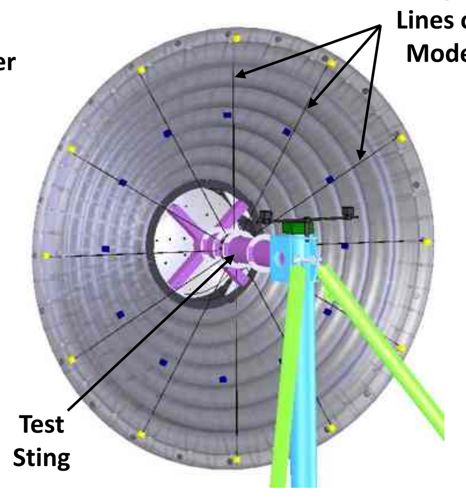
Challenges:
- 2D measurements required
- Integrated sensor system mounting configuration
- Each sensor requires dedicated power regulation
- Test hardware mounting

String Pot | Rotary Sensor

Design Concept:
- **Teamed String Pot / Angular Transducer**
- To accurately depict movement in a 2D field the string pot will be teamed with an angular transducer to measure the angle at which the string pot line is deployed. This will be done by attaching an extension bar to the angular transducer that mimics the angle of the string pot. This sensor system will be mounted at two radial locations on the test sting to monitor aeroshell deformation.



Sensor System Prototype



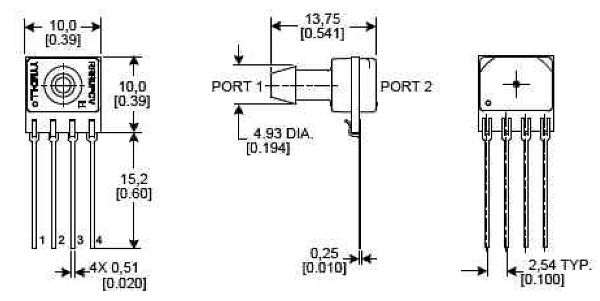
6.0 m HIAD Aft View

Flexible Aeroshell Pressure

MEMS Pressure Sensors

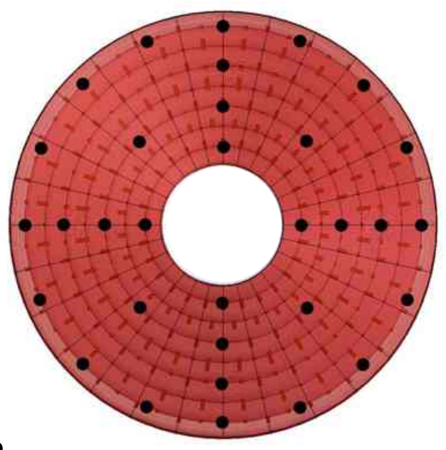
Pressure measurements on the flexible aeroshell will provide modeling validation while varying angle of attack.

Challenges:
- Integrating within a flexible substrate (flexibility, profile)
- Mitigating measurement errors due to pressure port design and surface roughness
- Peak vs. Valley Measurements

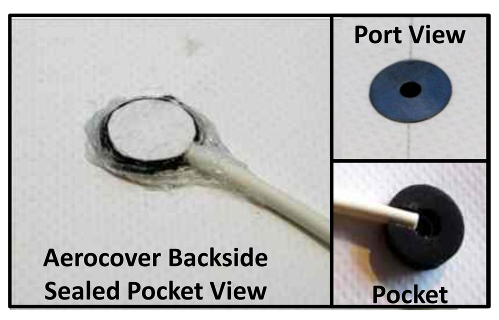


MEMS Pressure Sensor

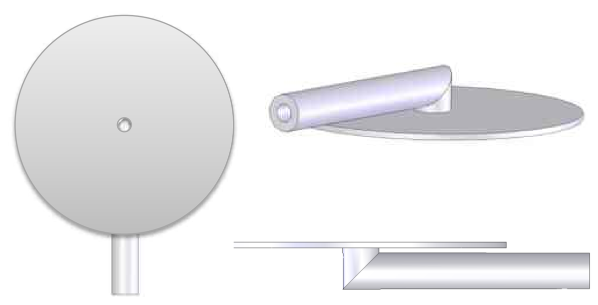
Design Concepts:
- **Right Angle Half Grommet**
- A custom designed half grommet pressure port will be mounted through the aerocover to provide a repeatable pressure port concept. Then pressure tubing mounted to the backside of the port will run to the MEMS pressure sensor.
- **Pressure Pocket w/ Shim Port**
- A custom pressure pocket has been designed to implement a protected, low profile, flexible pressure port. The pressure pocket is formed and protected by a rubber washer on the backside of the aerocover. This pocket is sealed using RTV. On the front face of the aerocover a machined metal shim acts as the pressure port. Pressure tubing mounted to the pocket runs to the MEMS pressure sensor.



Notional HIAD Port Layout



Pressure Pocket w/ Shim Port



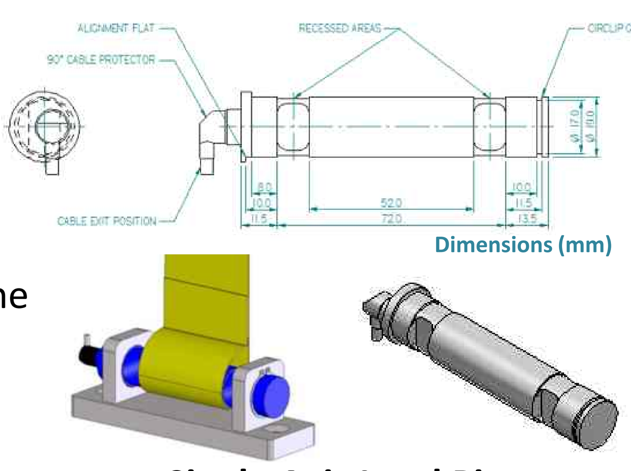
Right Angle Half Grommet

Structural Strap Loads

Single Axis Load Pins

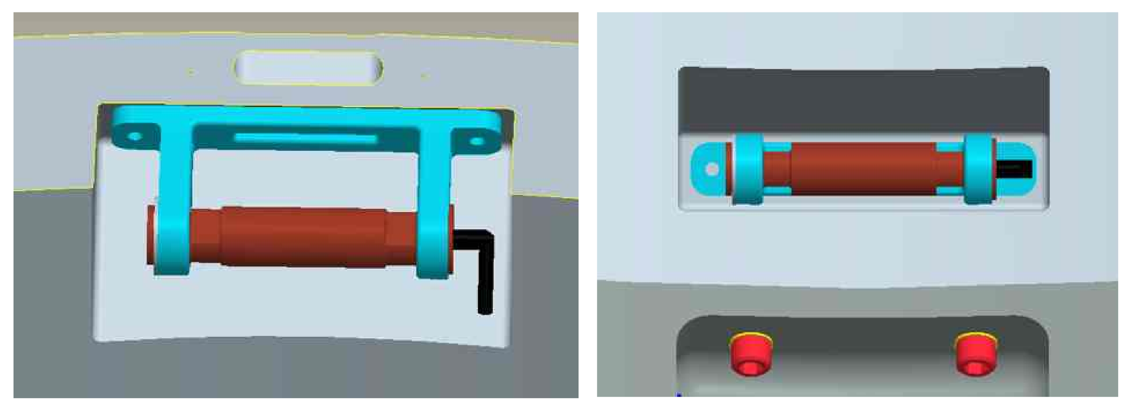
Custom Single Axis Load Pins from NovaTech will provide load measurements on the forward and aft structural straps.

Challenges:
- Measuring flexible material loads
- Providing a similar strength profile as to the solid clevis pins
- Characterizing loads on both the aft and forward structural straps



Single Axis Load Pin

Design Concept:
- **Strap Load Measurement Pins**
- The HIAD structural straps are anchored to the centerbody by integrated clevis pins. To measure the loads on the structural straps custom designed single axis load pins have been designed by NovaTech. The load pins will require a modified clevis to adapt to the greater pin diameter as compared to the standard clevis pin. These pins will be placed at selected forward and aft strap mounting locations. The pins will then be monitored by the NFAC to provide real-time load monitoring.



Load Pins Mounted in HIAD Centerbody

Structural Strap Strain

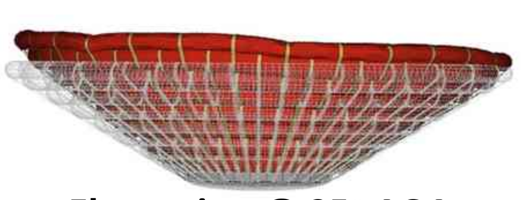
High Tension String Potentiometers

String pots will be used to measure the elongation of the HIAD forward primary structural strap.

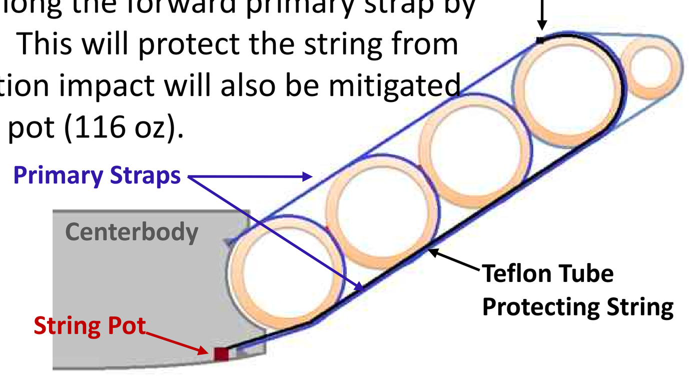
Challenges:
- Measuring strain of woven materials
- Designing a flexible low profile system that allows the string to travel unimpeded under aero loading (mitigating string friction and aero loading force)

High Tension String Pot

Design Concept:
- **Teflon Tube Guide**
- The string pot line will be guided along the forward primary strap by a 1/8" OD Teflon low friction tube. This will protect the string from pinching due to aero loading. Friction impact will also be mitigated by employing a high tension string pot (116 oz).



Elongation @ 25º AOA



Structural Strap Strain Concept

Data Acquisition

Zigbee Wireless Transceivers

To mitigate massive wire bundles and feedthroughs wireless data acquisition will be utilized on a subset of the sensors systems.

Challenges:
- Mitigating massive wire bundle to power and monitor the 100+ sensors
- Reduce facility costs and complexity tied to each sensor signal
- Long Transmission Distances

Design Concept:
- **Wireless Data Acquisition**
- Multiple wireless data acquisition nodes will be implemented to mitigate the required wiring need to monitor the sensors. Each node will transmit to a base station located in the NFAC T-frame that will convert the wireless data to a RS-232 protocol. Then two RS-232 to fiber optic converters will be employed to transmit the serial data 100+ ft to a laptop computer.

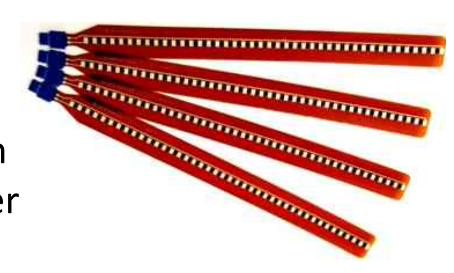
Wireless Node

Aerocover Scalloping

Uni-Directional Bends Sensors

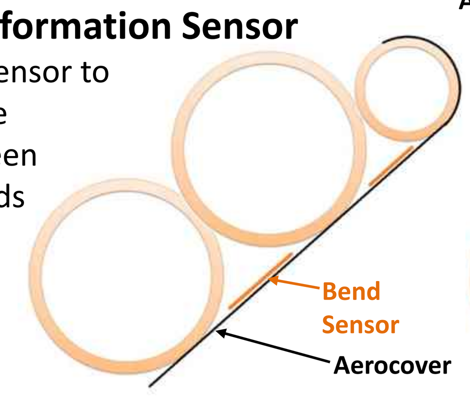
Bend sensors will be employed to indicate the magnitude of scalloping in the aerocover due to the aero loading.

Challenges:
- The aerocover profile must be known to determine the magnitude of scalloping (Each angle of attack will have a different aerocover scallop geometry)
- Relating measurement to deflected geometry

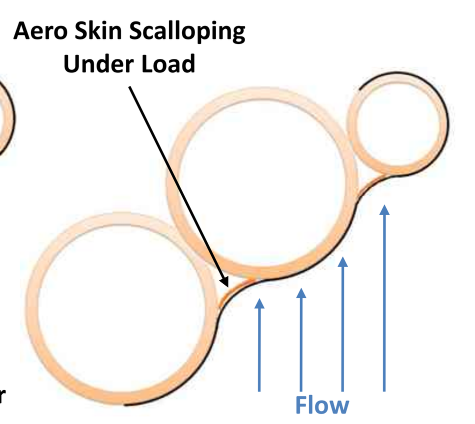


Bend Sensors

Design Concept:
- **Embedded Deformation Sensor**
- Adhere the bend sensor to the back side of the aerocover in between the inflatable toroids to measure the scalloping.



Aeroshell Section – Under No Aero Load



Aeroshell Section – Under High Aero Load

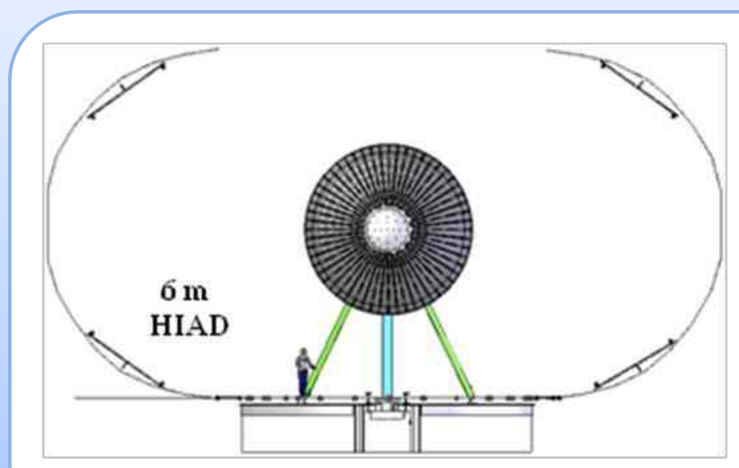
Large Scale HIAD Wind Tunnel Test Series

Location: National Full-Scale Aerodynamics Complex (NFAC) at NASA ARC

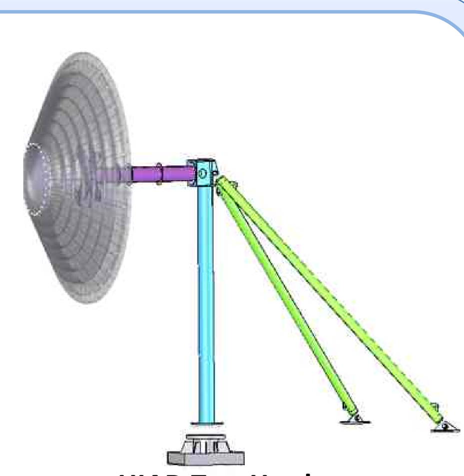
Primary Objective:

Characterize the 6.0 and 8.3 m diameter HIAD response to changes in dynamic pressures and angle of attack over the range of expected flight conditions for a representative LEO re-entry demonstration mission. The HIAD test model response's will be correlated to the structural simulation model. Measurements for model correlation include inflatable surface displacement, surface pressures and structural strap loads.

Secondary Objectives:
- Determine a minimum inflation pressure needed to maintain structural stiffness and stability over the test conditions.
- Evaluate the HIAD response to failure modes with loss of torus pressure.
- Evaluate performance of developmental instrumentation and pursue embedded flight instrumentation.



6 m HIAD in NFAC 40 x 80 Wind Tunnel



HIAD Test Hardware

Acknowledgments

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