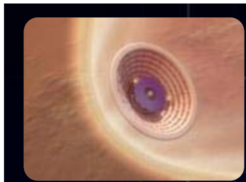


Design and Execution of the Hypersonic Inflatable Aerodynamic Decelerator Large-Article Wind Tunnel Experiment

Alan M. Cassell

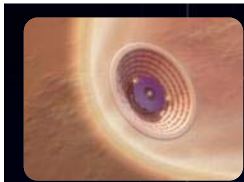
NASA Ames Research Center, Entry Systems and Vehicle Development Branch

10th International Planetary Probe Workshop, 17-21 June 2012, San Jose, CA, USA

Outline

- HIAD Overview
- Test Design
- Assembly & Integration
- Testing Operations
- Instrumentation & Data Produ
- Summary

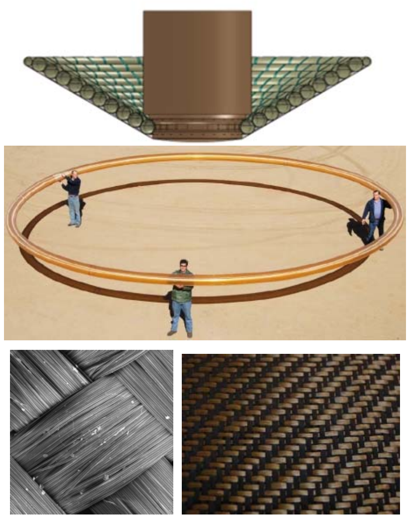

Photo credit: Dominic Hart



HIAD Overview

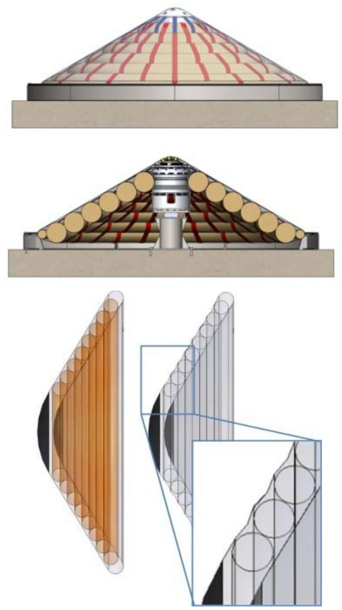
Inflatable Aeroshell Structures Development

Large-Scale Manufacturability & Material Development



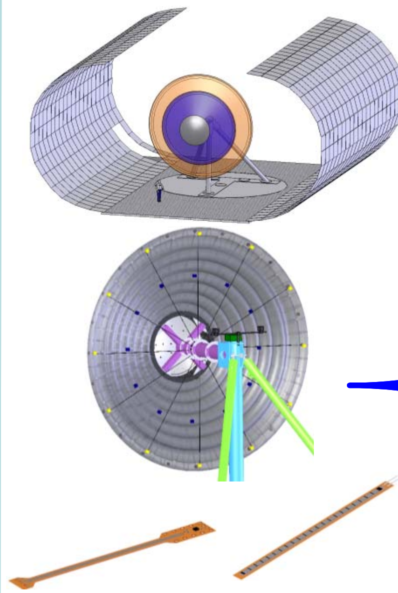
Development of large-scale manufacturing capabilities and advanced, high-temperature capable inflatable structure materials.

Large-Scale Static Load Testing & Model Development



Ground test to demonstrate HIAD scalability and initial structural model development.

Large-Scale Wind Tunnel Testing & Instrumentation Development

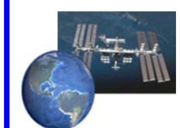


Ground tests to characterize HIAD performance under flight-like aerodynamic loading.

3 – 15-meter HIAD Class

Mars robotic (SMD & ESMD)

Venus missions (SMD)



LEO/ISS missions (SMD & SOMD)

NEO return-robotic (SMD & ESMD)

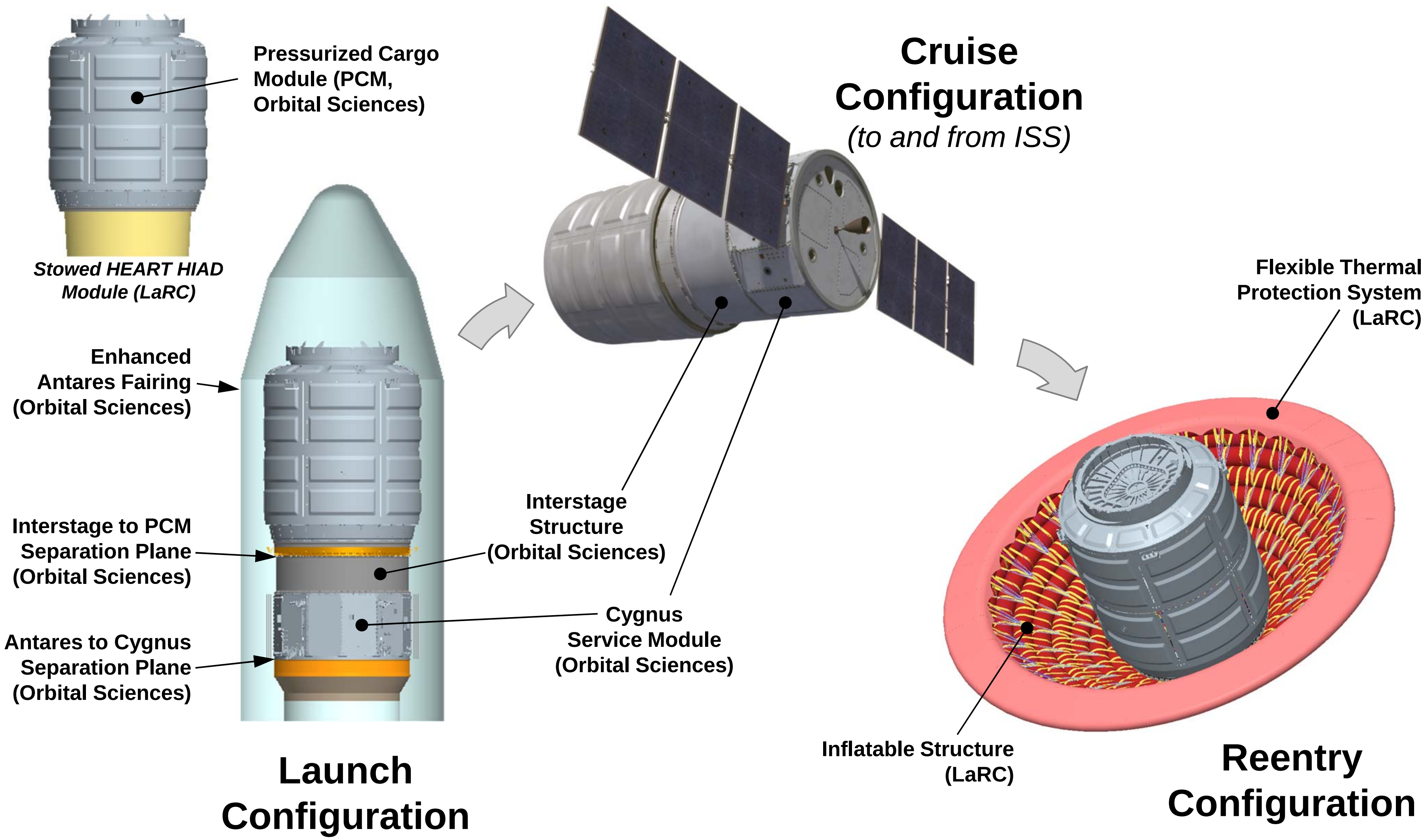
Lunar return-robotic (SMD & ESMD)

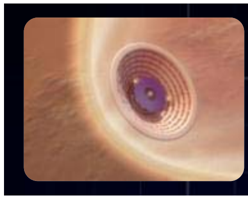
Terrestrial robotic missions (DoD)


Technology development & risk reduction for Human Mars missions (ESMD)

HIAD Overview

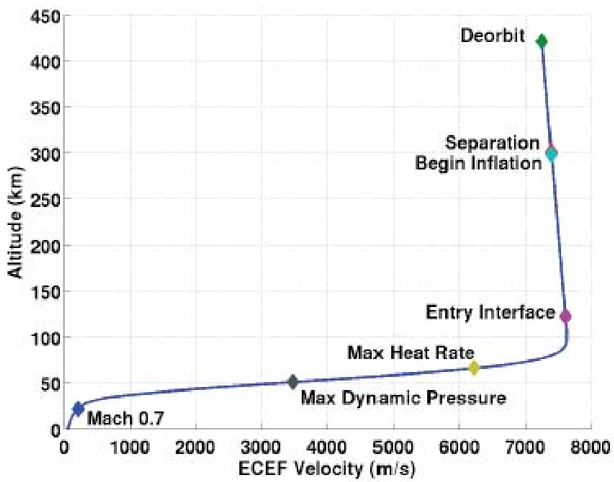
The HIAD Mission Concept- HEART

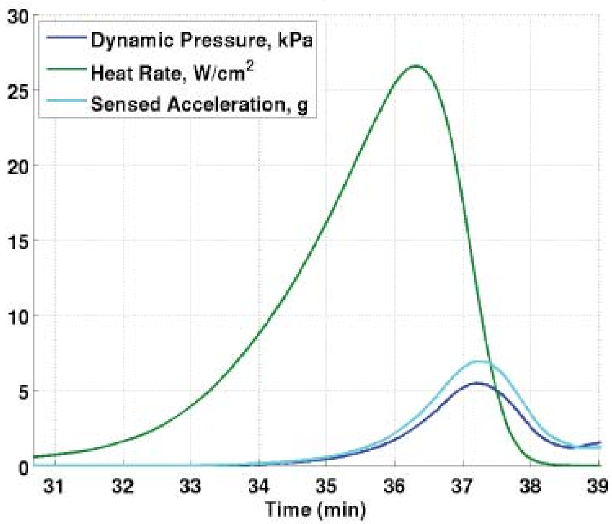


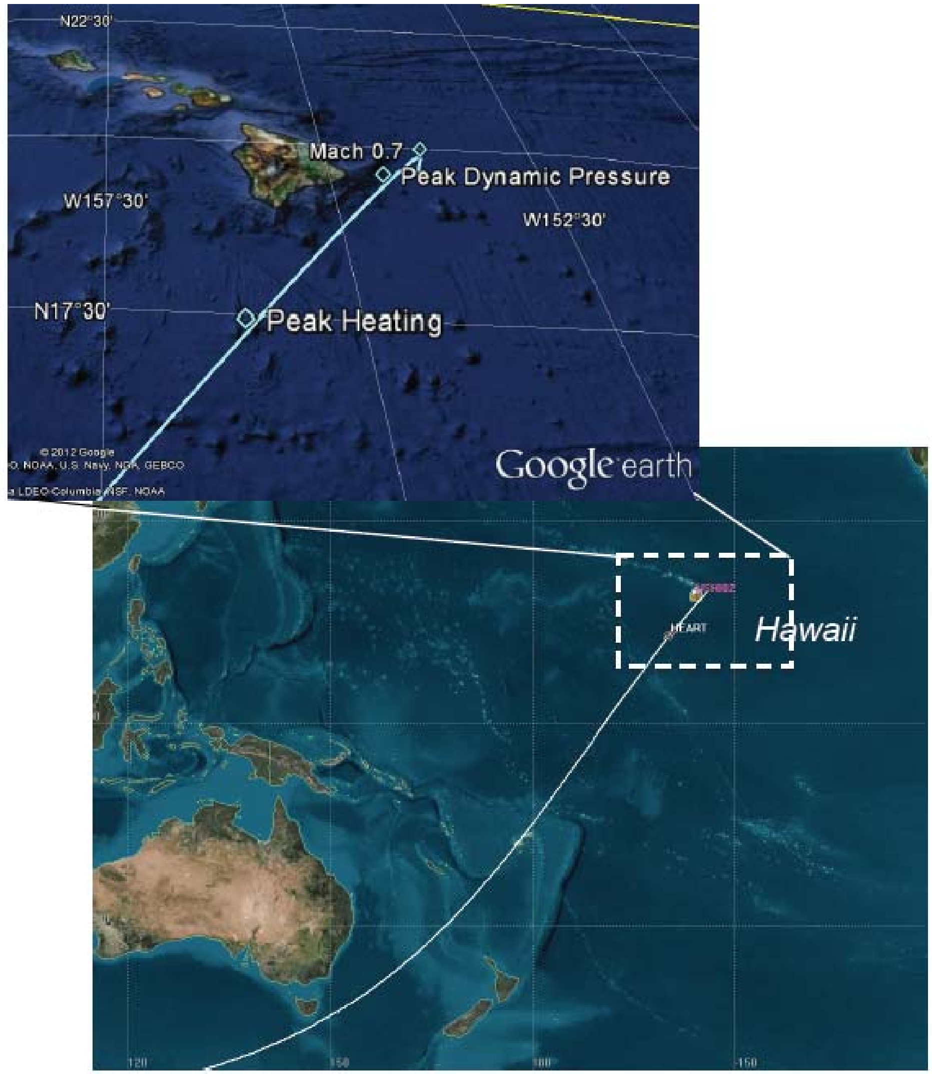


HIAD Overview

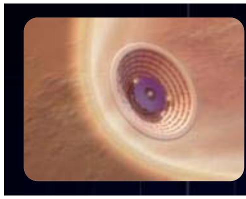
HEART Trajectory





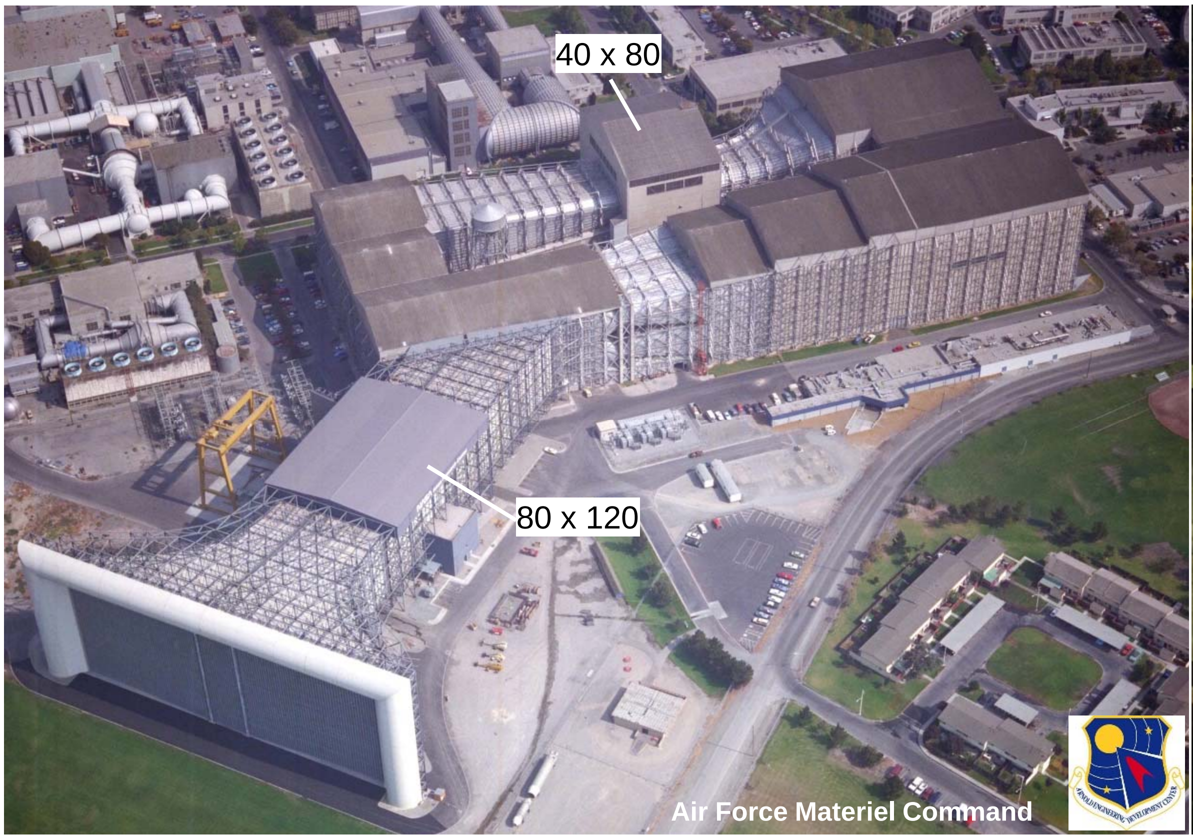


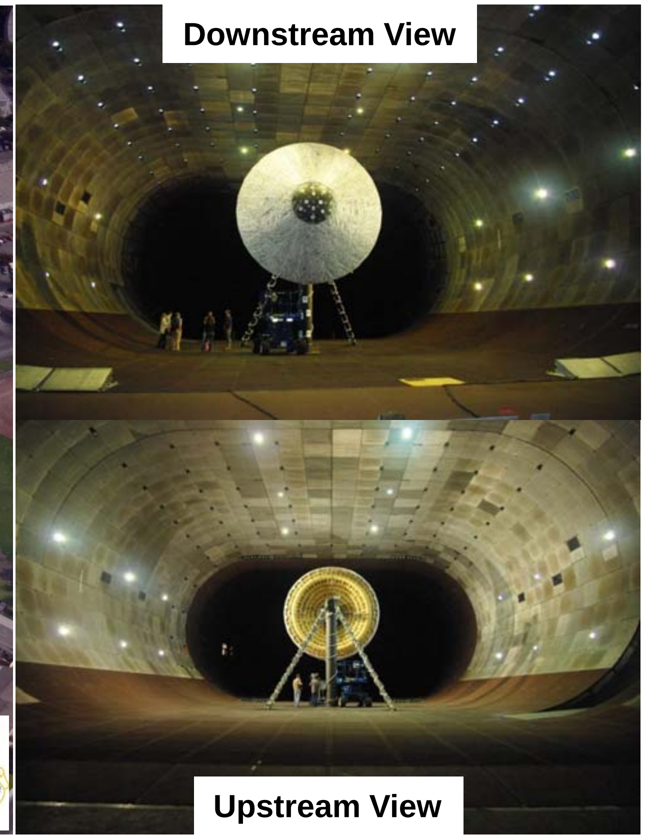
Unmargined aerothermal environments



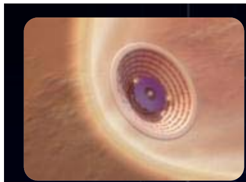
Test Design

National Full-Scale Aerodynamics Complex





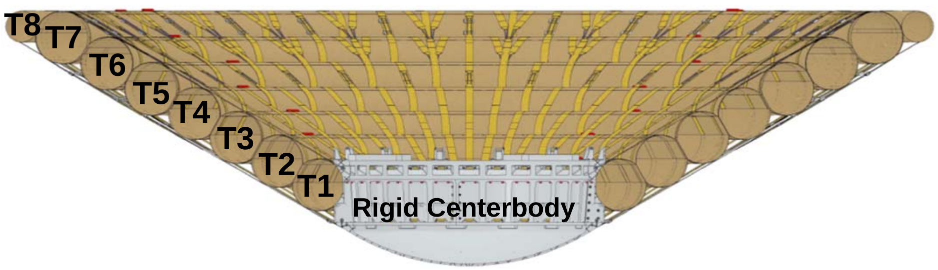
<u>40 ft x 80 ft (12 m x 24 m) Test Section Operating Specifications</u>
Semi-Elliptical Profile
Maximum Velocity- 300 knots (154 m/s)
Max Dynamic Pressure- 262 psf (12.5 kPa)
*Max Drag Load- 32,000 lbs



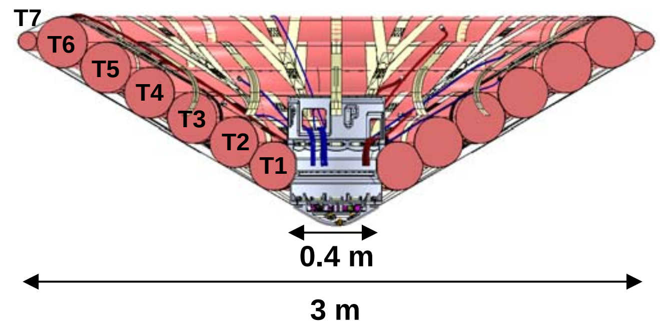
Test Design

Test Article Descriptions

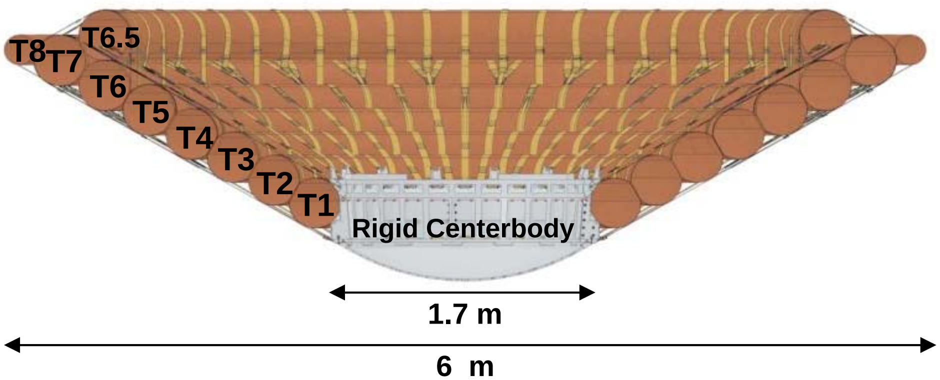
6 m Baseline



3 m



6 m Tri-Torus



Test Design

Test Matrix

6m Tri-Torus Configuration

I2 Inflation State

Q (psf)	Angle of Attack (deg) -25	-20	-15	-10	-5	0	5	10
0/8						X		
35						X		
40	X		X		X	X	X	X
50	X		X	X	X	X	X	X
64			X		X	X		

I3 Inflation State

Q (psf)	Angle of Attack (deg) -25	-20	-15	-10	-5	0	5	10
0/8						X		
30						X		
40	X	X	X	X	X	X	X	X
50	X	X	X	X	X	X	X	X
64		X	X	X	X	X	X	X

I4 Inflation State

Q (psf)	Angle of Attack (deg) -25	-20	-15	-10	-5	0	5	10
0/8						X		
30						X		
40			X	X	X	X	X	X
50			X	X	X	X	X	X
64						X		

6m Baseline Configuration

I2 Inflation State

Q (psf)	Angle of Attack (deg) -25	-20	-15	-10	-5	0	5	10
0/8						X		
35						X		
40	X		X		X	X		
50	X		X		X	X	X	X
70	X		X		X	X		

I3 Inflation State

Q (psf)	Angle of Attack (deg) -25	-20	-15	-10	-5	0	5	10
0/8						X		
35						X		
40	X		X		X	X		
50	X		X		X	X	X	X
70	X		X		X	X		

I4 Inflation State

Q (psf)	Angle of Attack (deg) -25	-20	-15	-10	-5	0	5	10
0/8						X		
35						X		
40	X		X		X	X		
50	X		X		X	X	X	X
70	X		X		X	X		

3m without TPS

I1 Inflation State

Q (psf)	Angle of Attack (deg) -10	-5	0	5	10
8	X	X	X	X	X
40	X	X	X		
80	X	X	X	X	X
120	X	X	X	X	
160					

I2 Inflation State

Q (psf)	Angle of Attack (deg) -10	-5	0	5	10
8	X	X	X	X	X
40	X	X	X		
80	X	X	X	X	X
120		X	X	X	X

I4 Inflation State

Q (psf)	Angle of Attack (deg) -10	-5	0	5	10
8	X	X	X	X	X
40	X	X	X		
80	X	X	X		
120	X	X	X		

3m with TPS

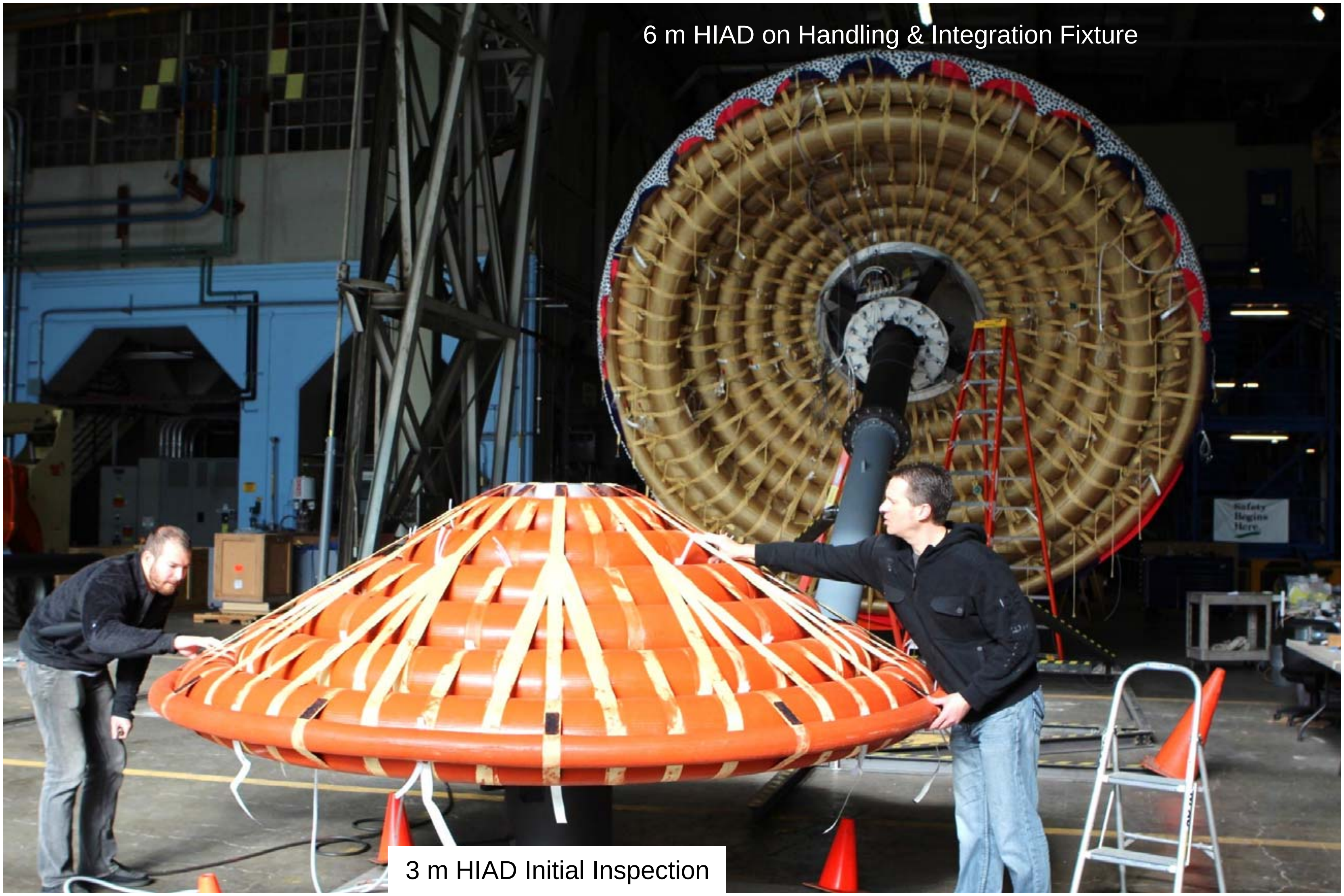
I1 Inflation State

Q (psf)	Angle of Attack (deg) -10	-5	0	5	10
8	X	X	X	X	X
40	X	X	X		
80	X	X	X	X	X
120	X	X	X	X	X
160		X	X		

Testing Approach

- Test from highest to lowest inflation setting
- Stabilize tunnel condition ***q***, then do AoA sweeps
- ~60 sec dwell time at each point for data acquisition
- Slew rate for turntable (0.5 deg/sec)
- 379 total test points (with repeats) obtained

Test Article Preparations



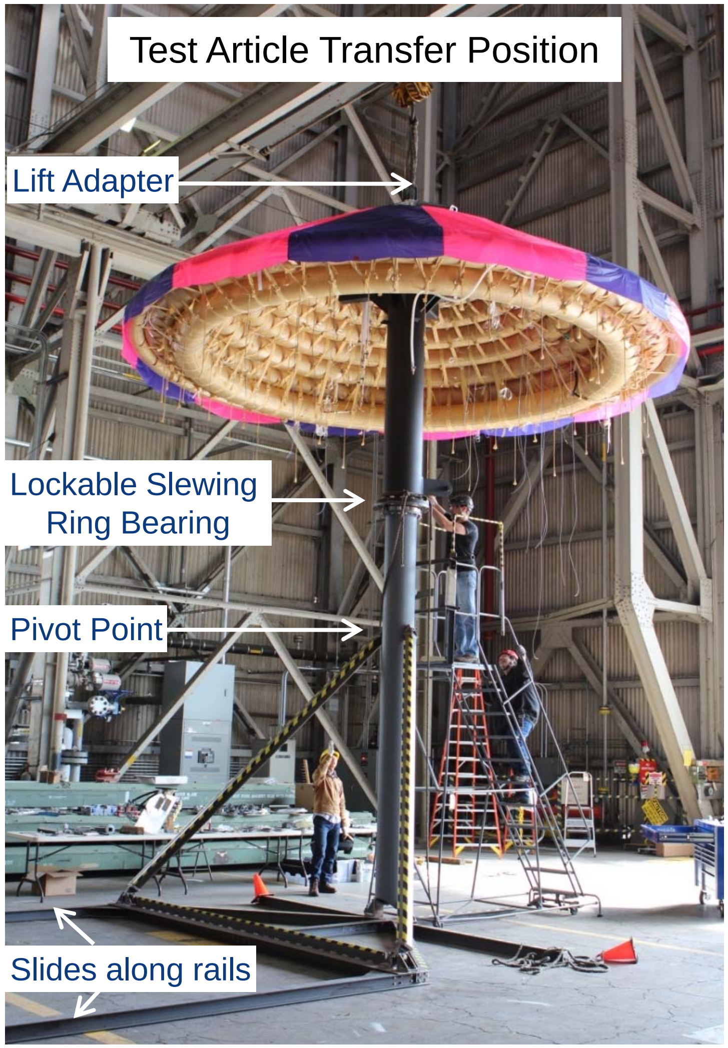
Custom Handling & Integration Fixture

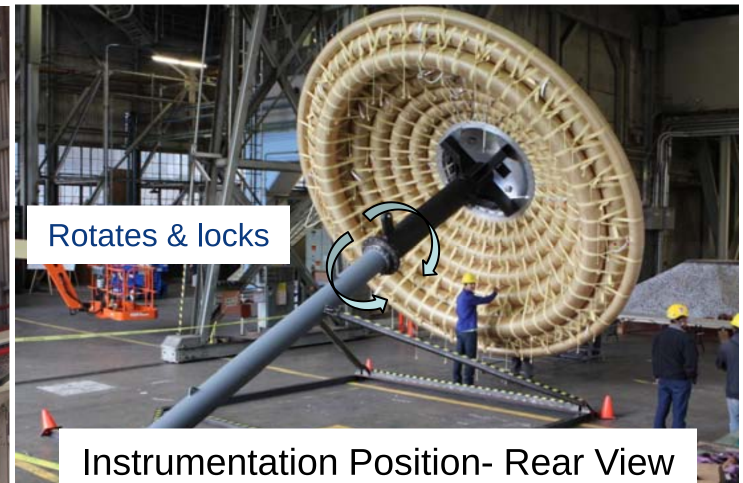
Key Features:

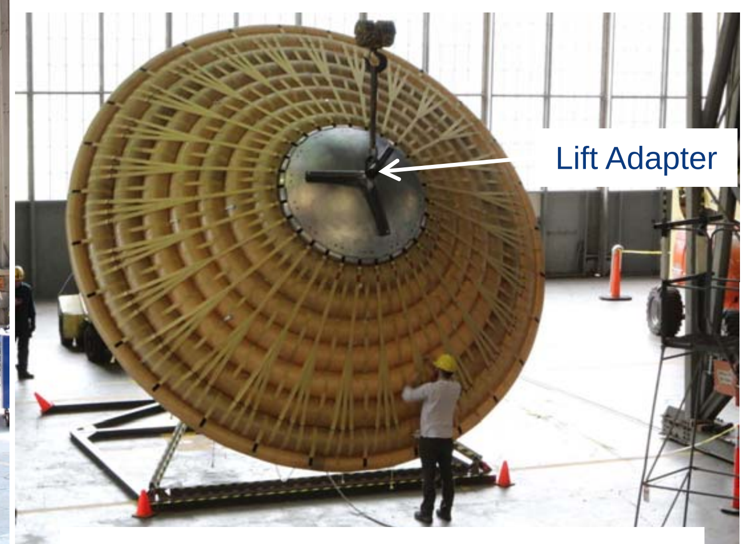
- Tilt via Facility Cranes to Transfer/Integration Positions
- Manually Rotatable via Bearing
- Radial Rotation Lock

Allows:

- Facile Access- Fore & Aft
- Rapid Instrumentation & Pneumatic Line Integration
- Transfer to/from Test Section





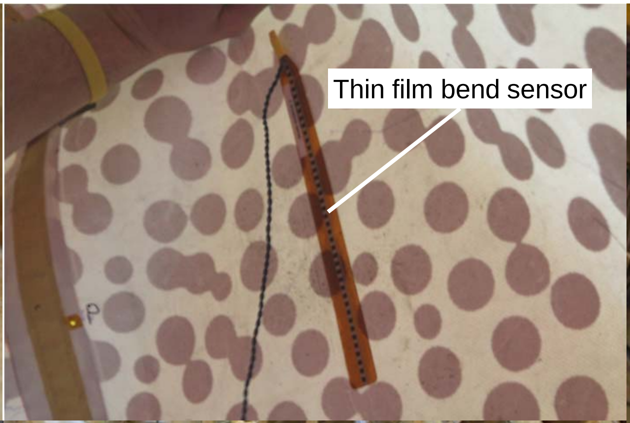


Instrumentation Position- Front View

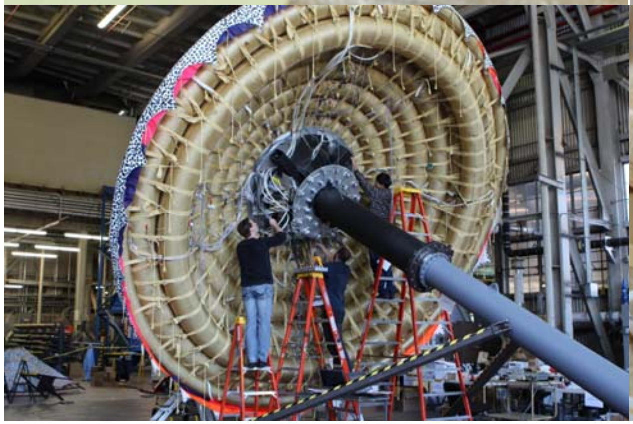
Instrumentation & Pressure Line Set-Up

Instrumentation Feed-thrus

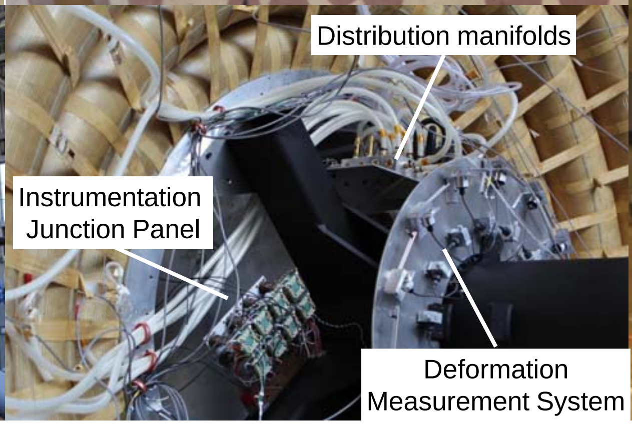
Developmental Instrumentation



Inflation Manifold



Routing Instrumentation & pneumatic lines



Sting/Test Article Interface

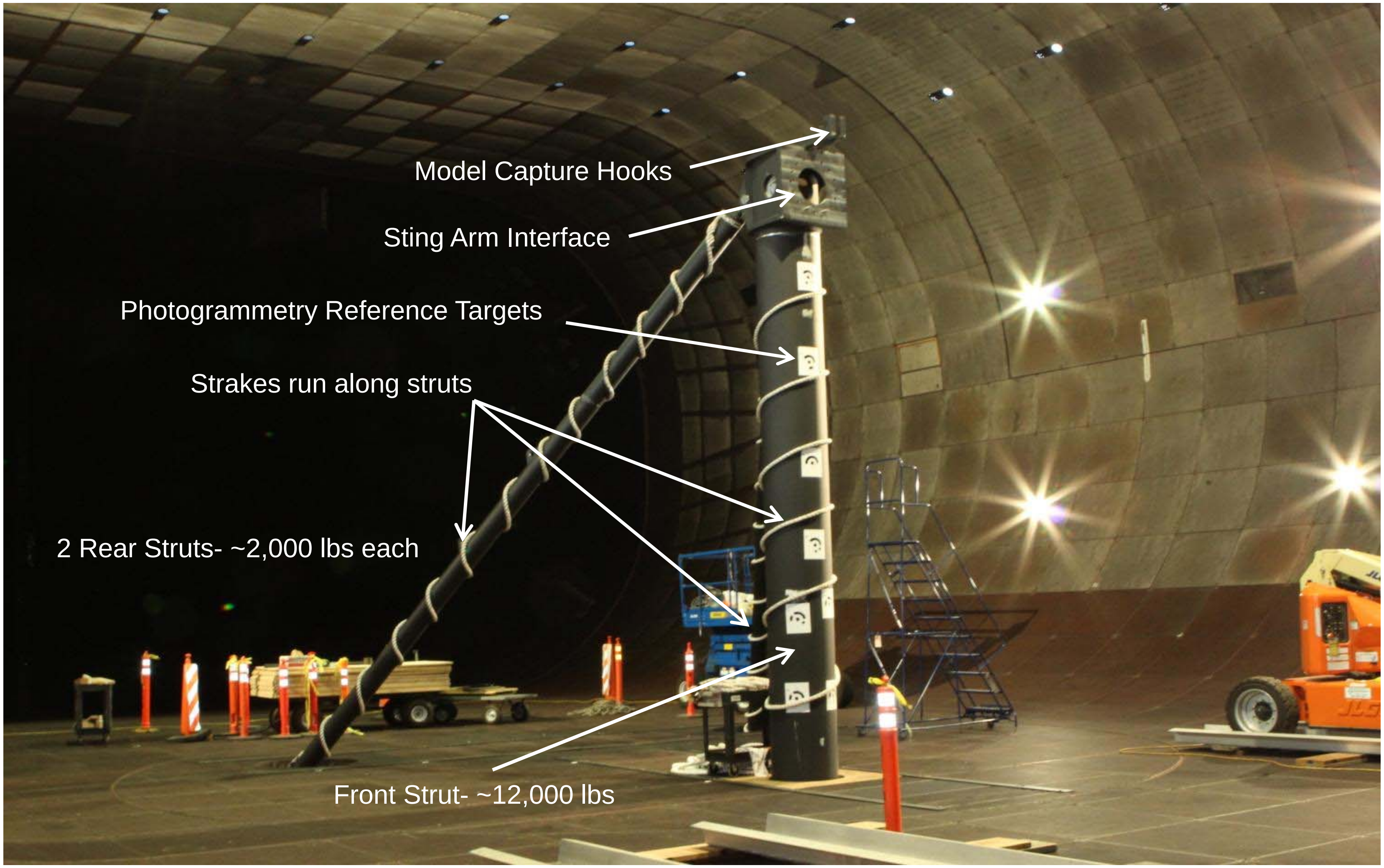
Assembly & Integration

6 m Aerocover Install

Aerocover Transferred from Integration Fixture to 6 m HIAD using overhead crane in NFAC high bay

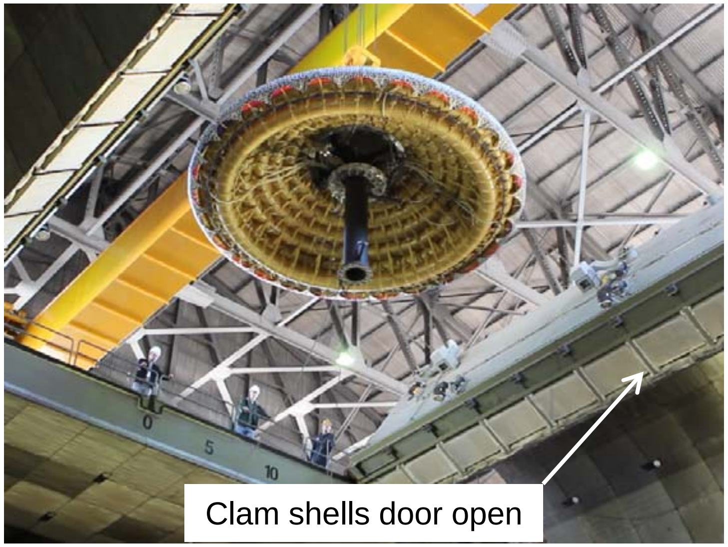
Aerocover Secured to 6 m Test Article

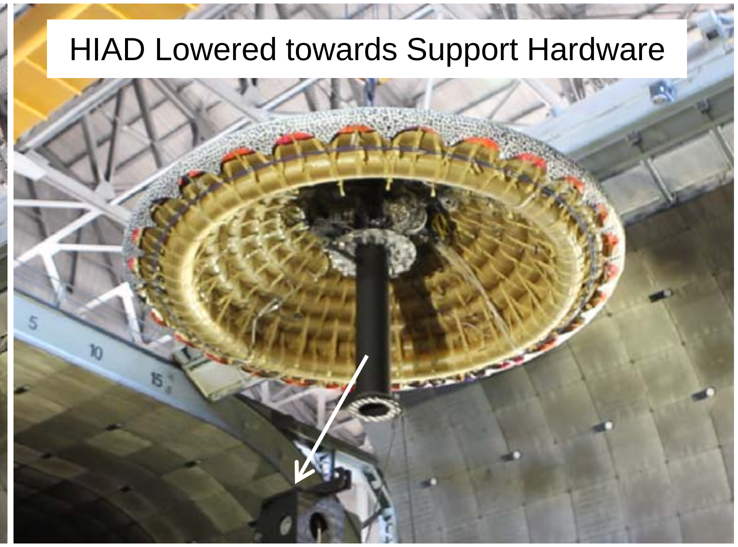
Custom Support System Hardware

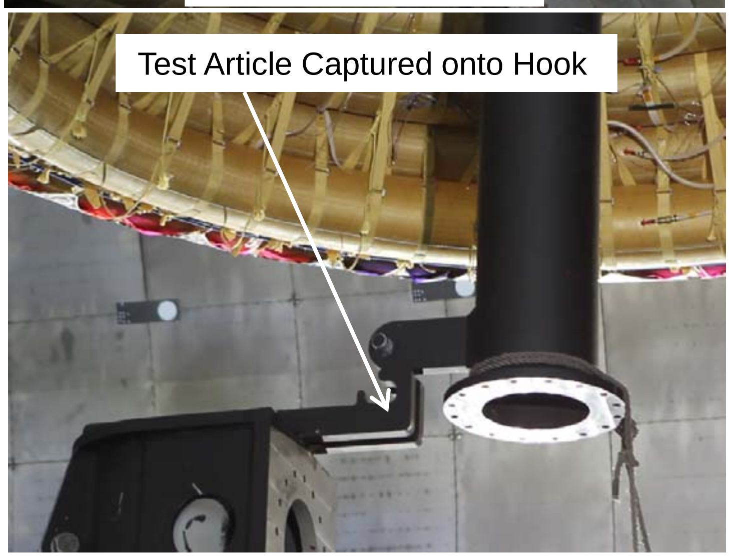


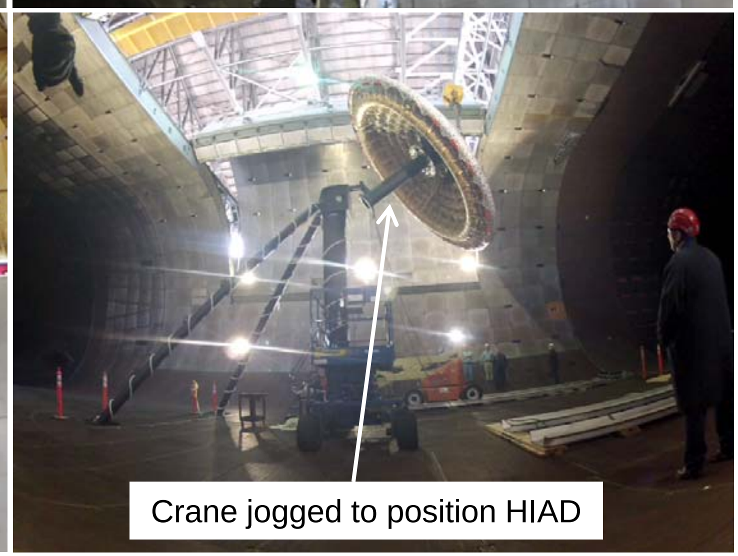
Assembly & Integration

Model Installation

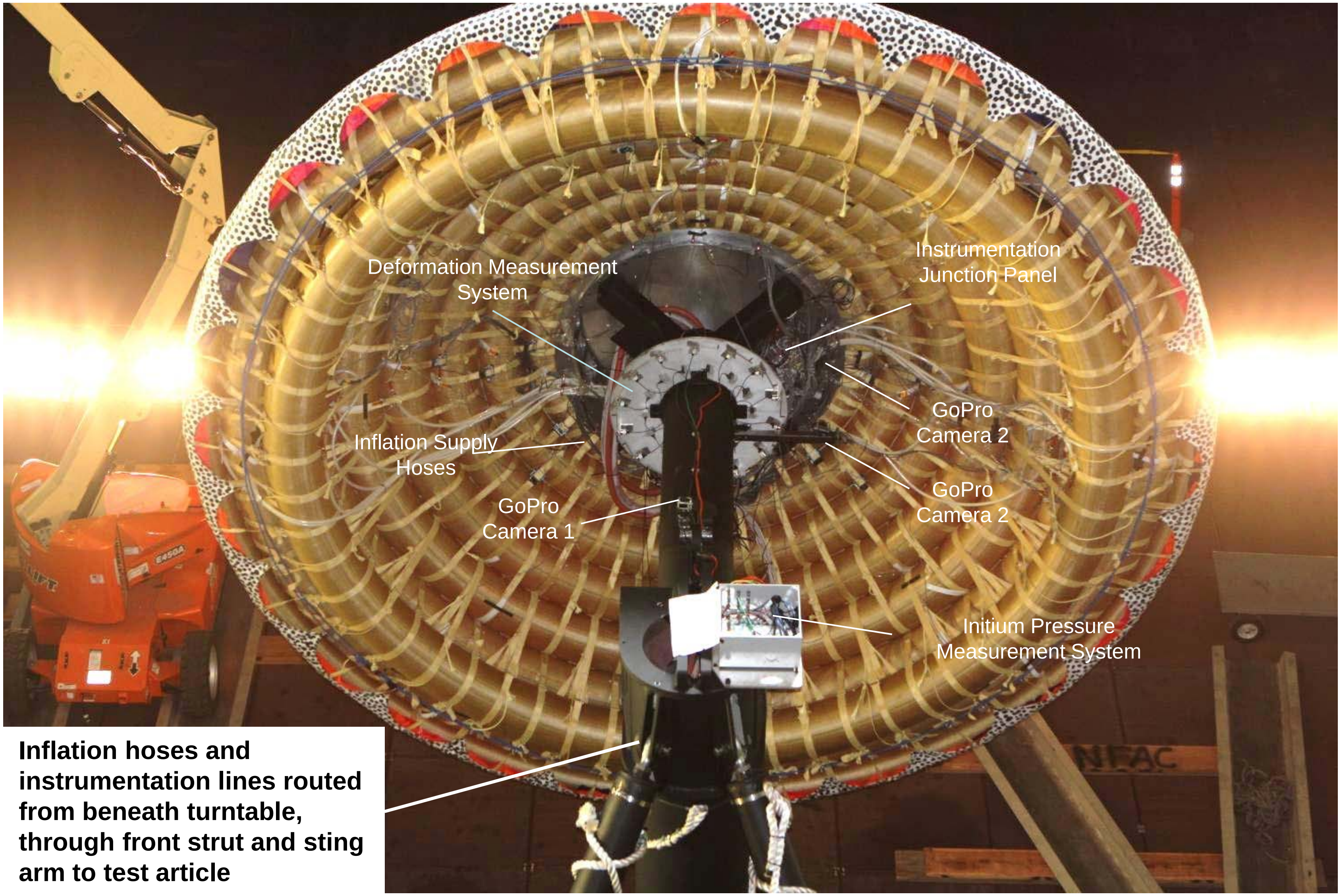








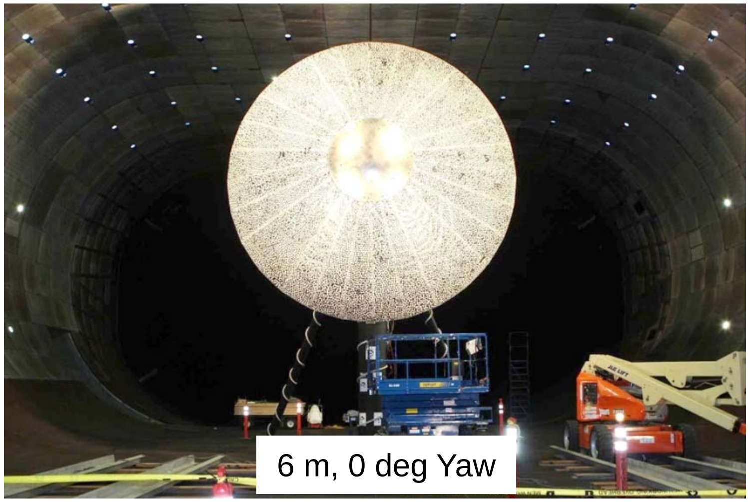
Final Assembly in Test Section

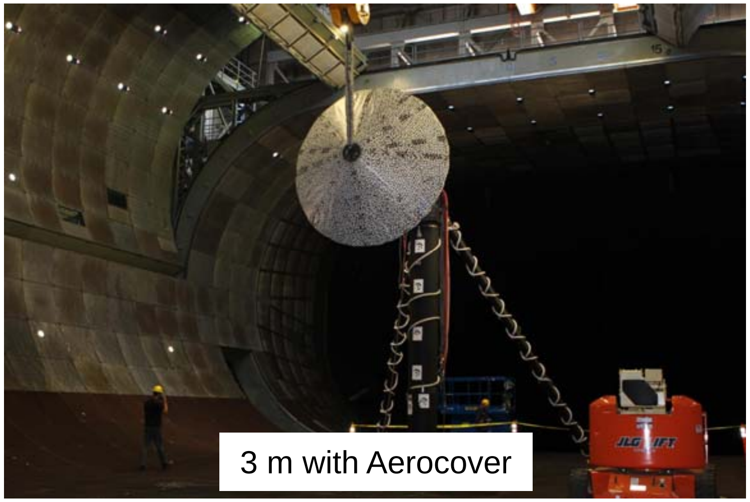


Inflation hoses and instrumentation lines routed from beneath turntable, through front strut and sting arm to test article

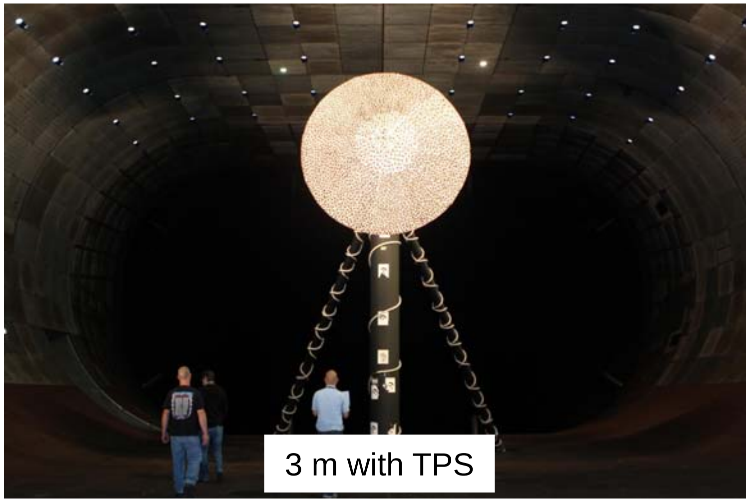
Test Operations

Test Articles Installed in Wind Tunnel


6 m, 0 deg Yaw


3 m with Aerocover


6 m, -25 deg Yaw

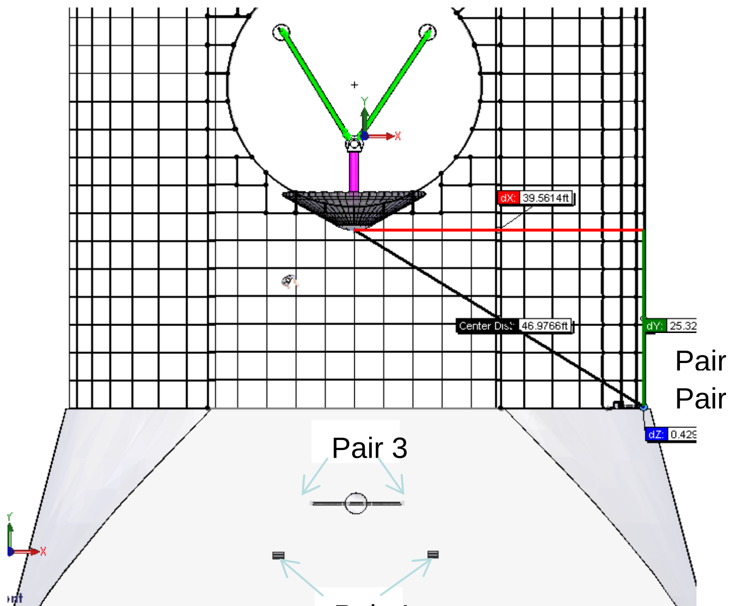

3 m with TPS

Test Operations

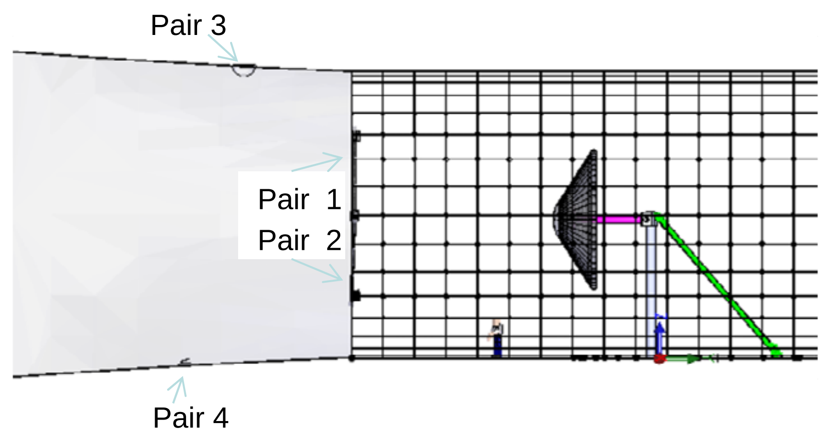
HIAD Video Compilation

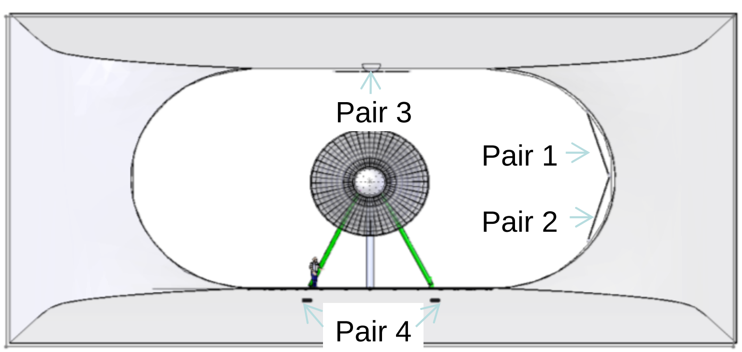
Photogrammetry System

Top View



Side View





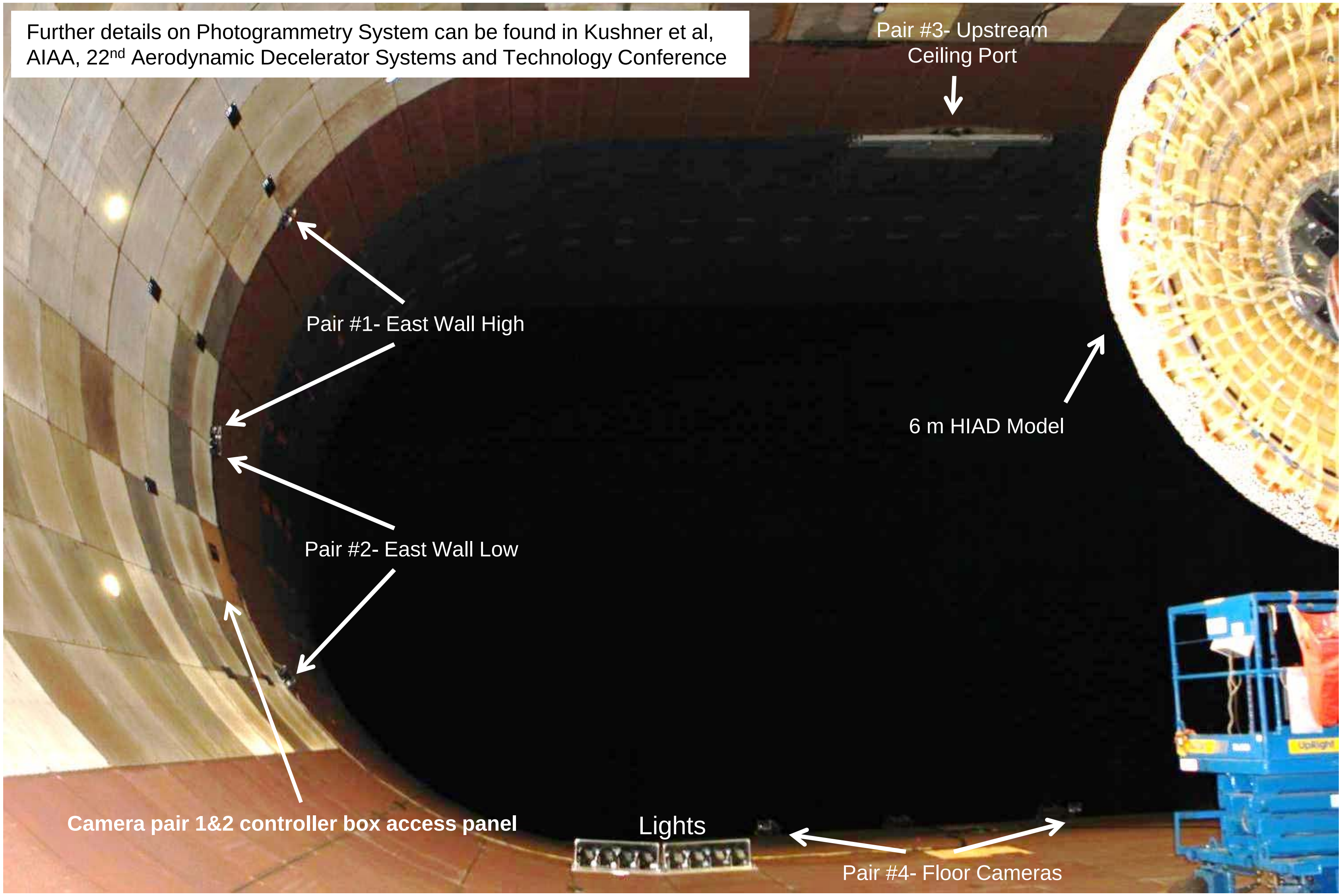
Front View

Pair	Location	Distance	Model Coverage
1	East High	45-47	6m at -15 deg or higher
2	East Low	45-47	6m at -15 deg or higher
3	Ceiling Dome	46	Upper portion of HIAD for most solutions
4	Mic Stands	53	Solutions used in all data

Summary Table

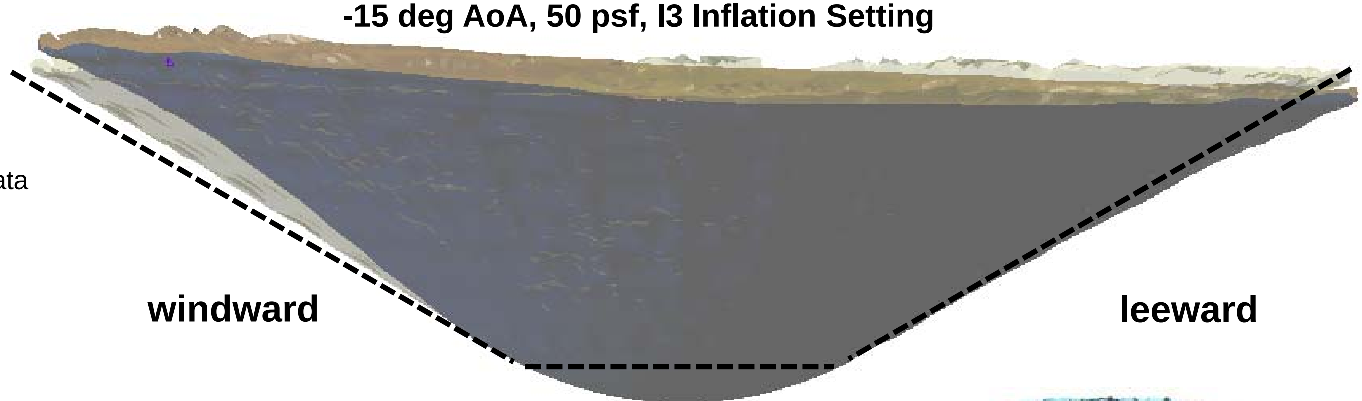
Photogrammetry System

Further details on Photogrammetry System can be found in Kushner et al, AIAA, 22nd Aerodynamic Decelerator Systems and Technology Conference



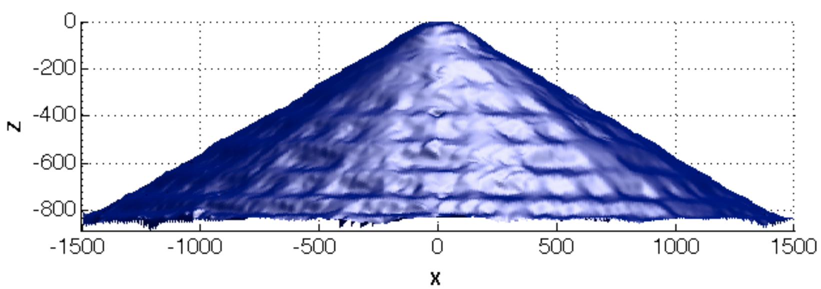
Photogrammetry Data

Overlay of Baseline (Dark Grey) on Tri-Torus
-15 deg AoA, 50 psf, I3 Inflation Setting

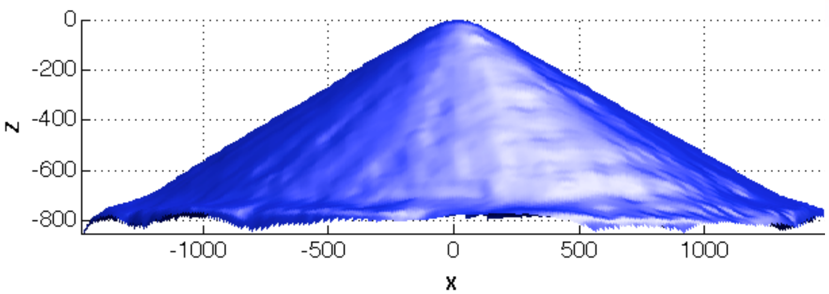


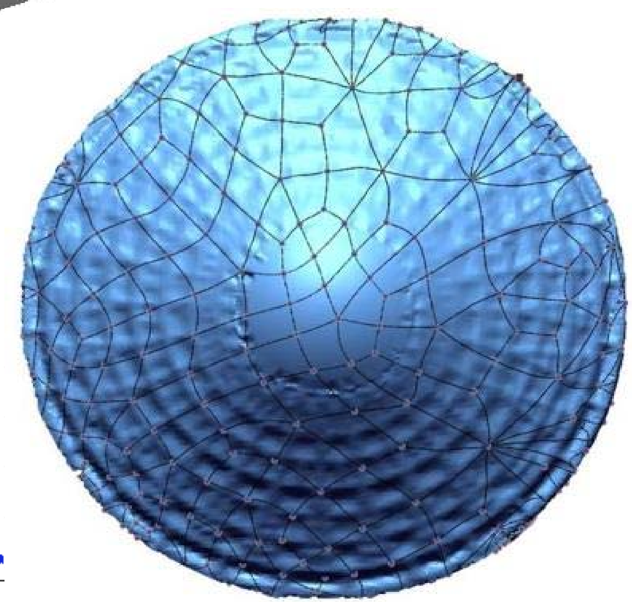
Further details on Photogrammetry Data can be found in Kazemba et al, AIAA, 22nd Aerodynamic Decelerator Systems and Technology Conference

3 m Aerocover

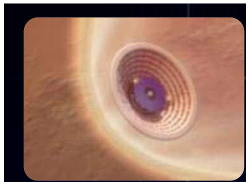


3 m w/ TPS



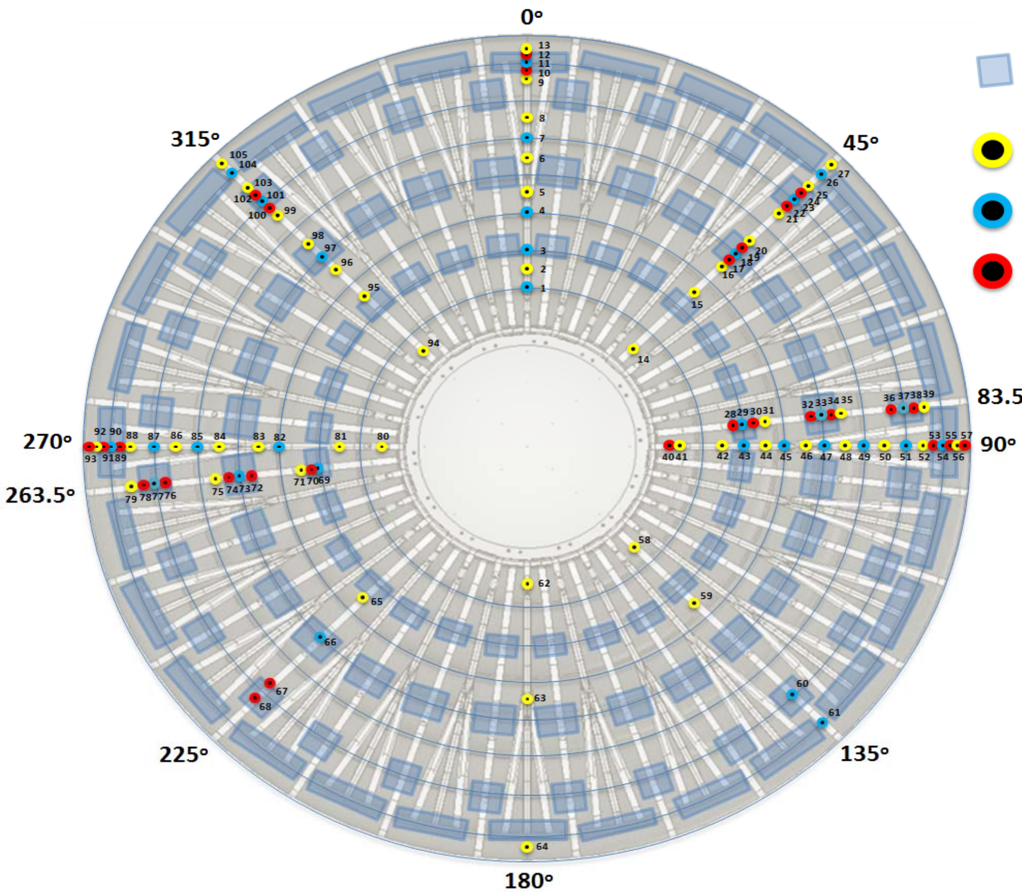


Deflected surface data ready for CFD grid generation



Instrumentation & Data Overview

Test Article Surface Pressures



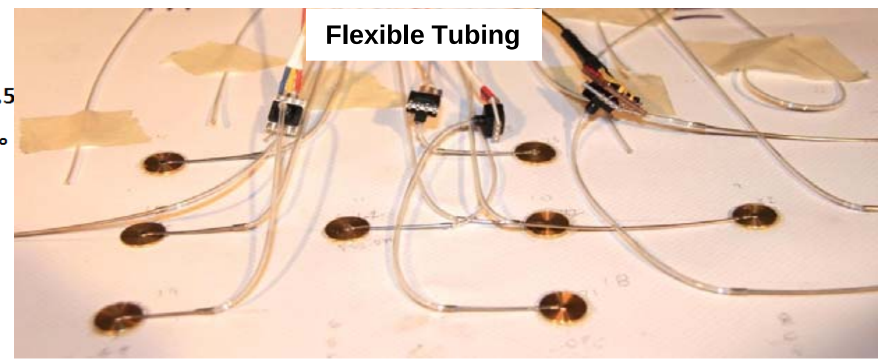
Large Unsupported (strap structure) Aerocover Areas – Most Likely Largest Areas of Deflection.

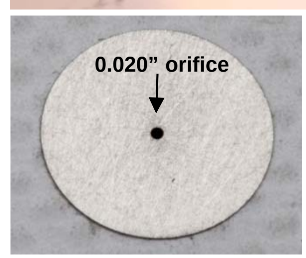
Pressure Tap on Torus Peak

Pressure Tap in Valley (minimum) of Tori

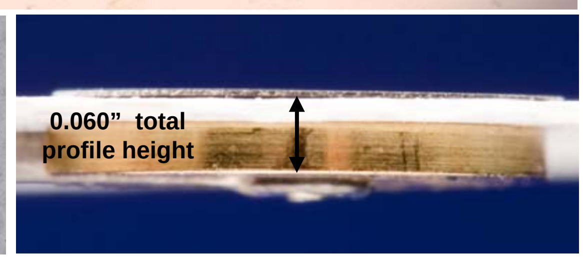
Pressure Tap Directly Between Torus Peak and Tori Valley

105 Embedded Pressure Taps



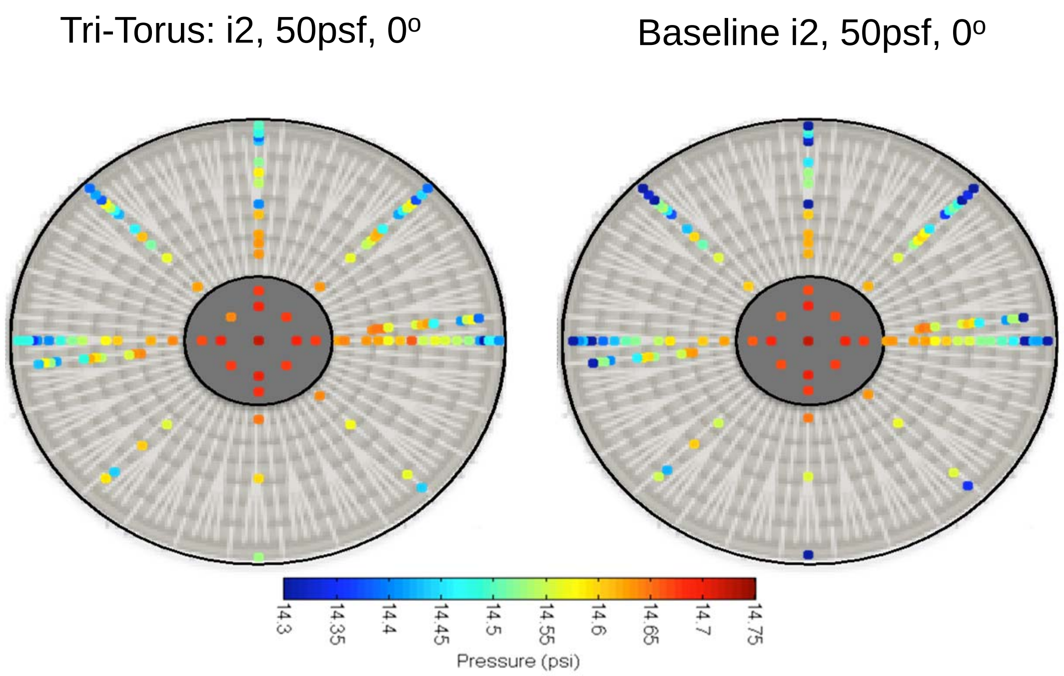


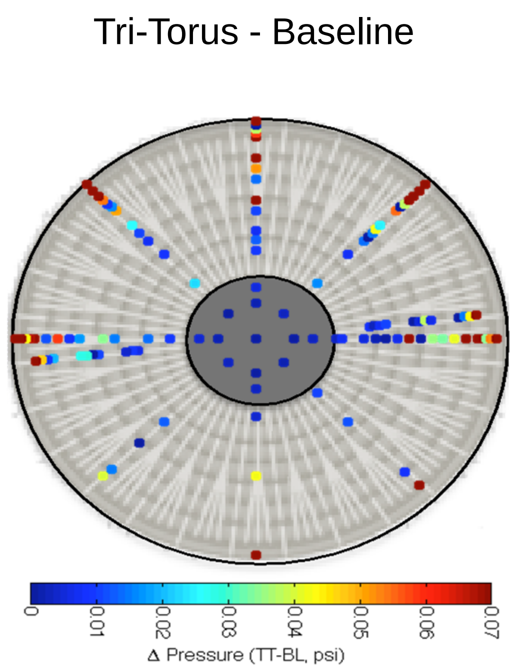
Tap Orifice

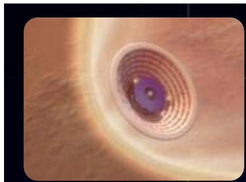


Low Profile Design

Surface Pressure Data

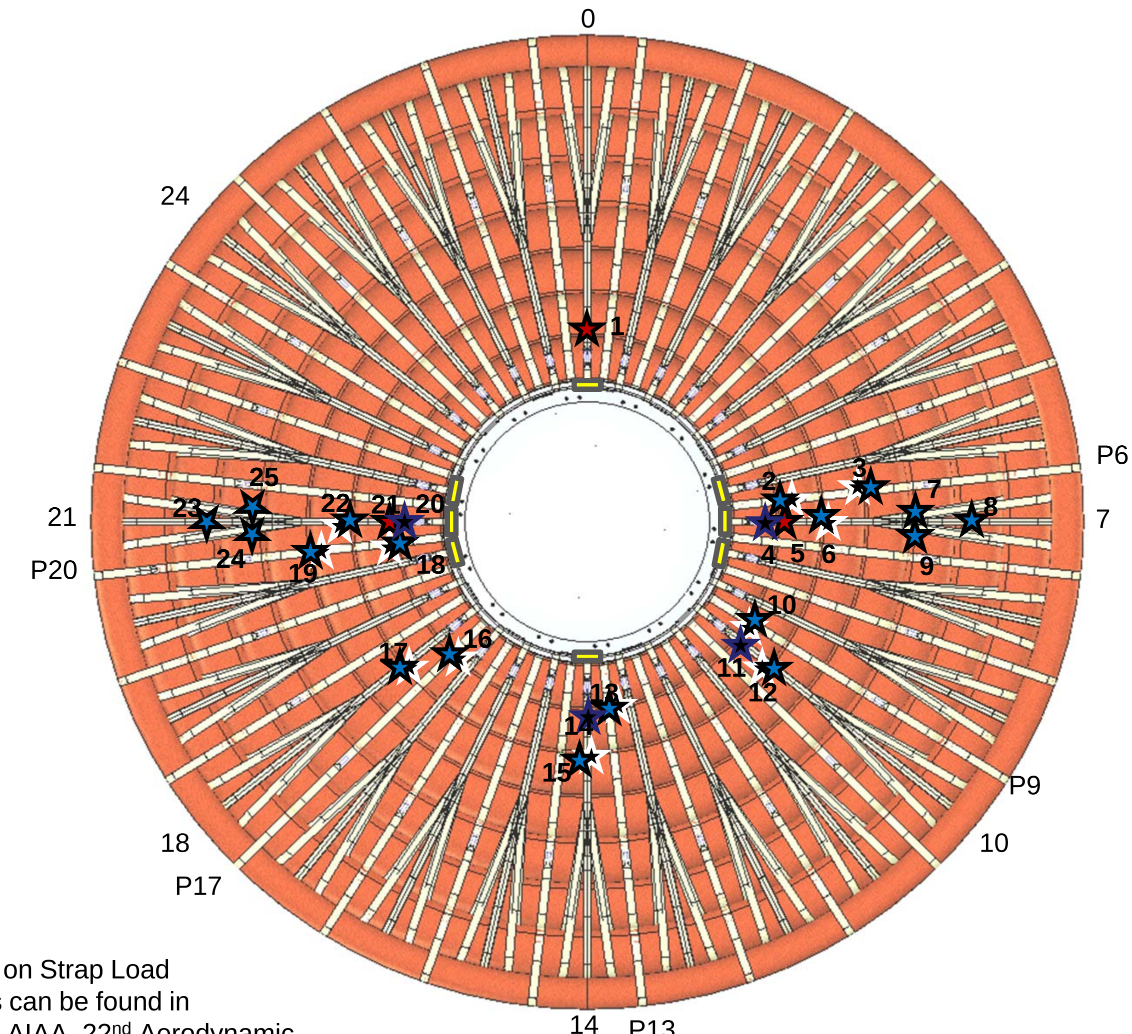






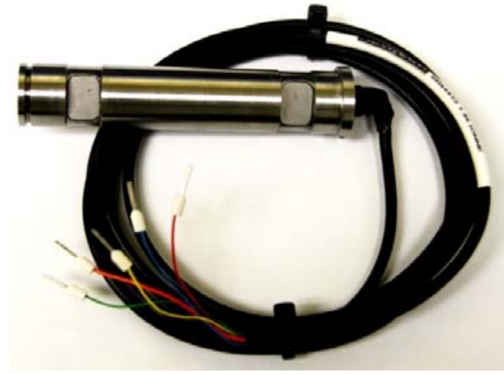
Instrumentation & Data Overview

Load Pins & Load Cells



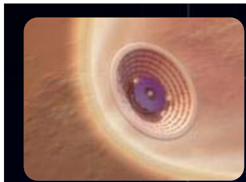
Load Cell Distribution Map

Load Pins- Yellow Bars



Strap Load Cells- Stars

Further details on Strap Load Measurements can be found in Swanson et al, AIAA, 22nd Aerodynamic Decelerator Systems and Technology Conference



Summary

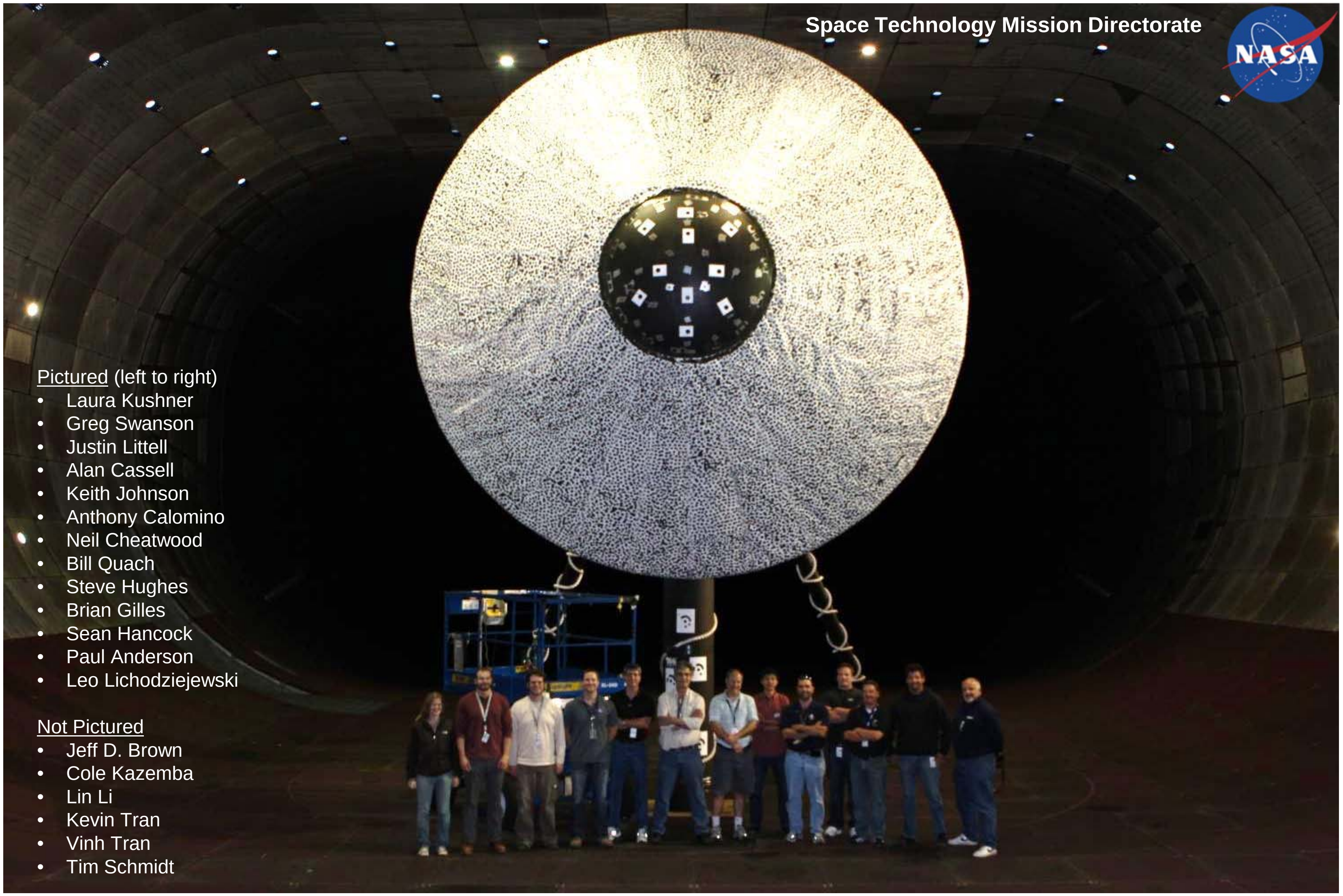
Results Overview

Summary:

- Very successful test series- all primary test objectives were met
- Two 6 m configurations and two 3 m configurations tested.
- Comprehensive set of data products- ~ 400 data channels monitored
- Ability to investigate Aero/Structural performance over a wide range of conditions
- Full 3-d imaging of forward surface for CFD & FEA model development
- Characterization methodology for structural strap materials
- Embedded instrumentation development for pressure and localized state measurements

Model Configuration	# Test Points	Primary Data Products						
		Photogrammetry	Strap Load Cells	Strap Load Pins	Surface Pressures	Wall Pressures	Aero Forces & Moments	Inflation Pressures
6 m Tri-Torus	151	Full Model Coverage	21	8	118	138	Yes	Yes
6 m Baseline	106	Full Model Coverage	21	8	118	138	Yes	Yes
3 m	94	Full Model Coverage	21	N/A	118	138	Yes	Yes
3 m w/ TPS	28	Full Model Coverage	21	N/A	5	138	Yes	Yes

Acknowledgements- Core Test Team



Pictured (left to right)
- Laura Kushner
- Greg Swanson
- Justin Littell
- Alan Cassell
- Keith Johnson
- Anthony Calomino
- Neil Cheatwood
- Bill Quach
- Steve Hughes
- Brian Gilles
- Sean Hancock
- Paul Anderson
- Leo Lichodziejewski

Not Pictured
- Jeff D. Brown
- Cole Kazemba
- Lin Li
- Kevin Tran
- Vinh Tran
- Tim Schmidt

Acknowledgements- Test Team Photo

Questions?

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