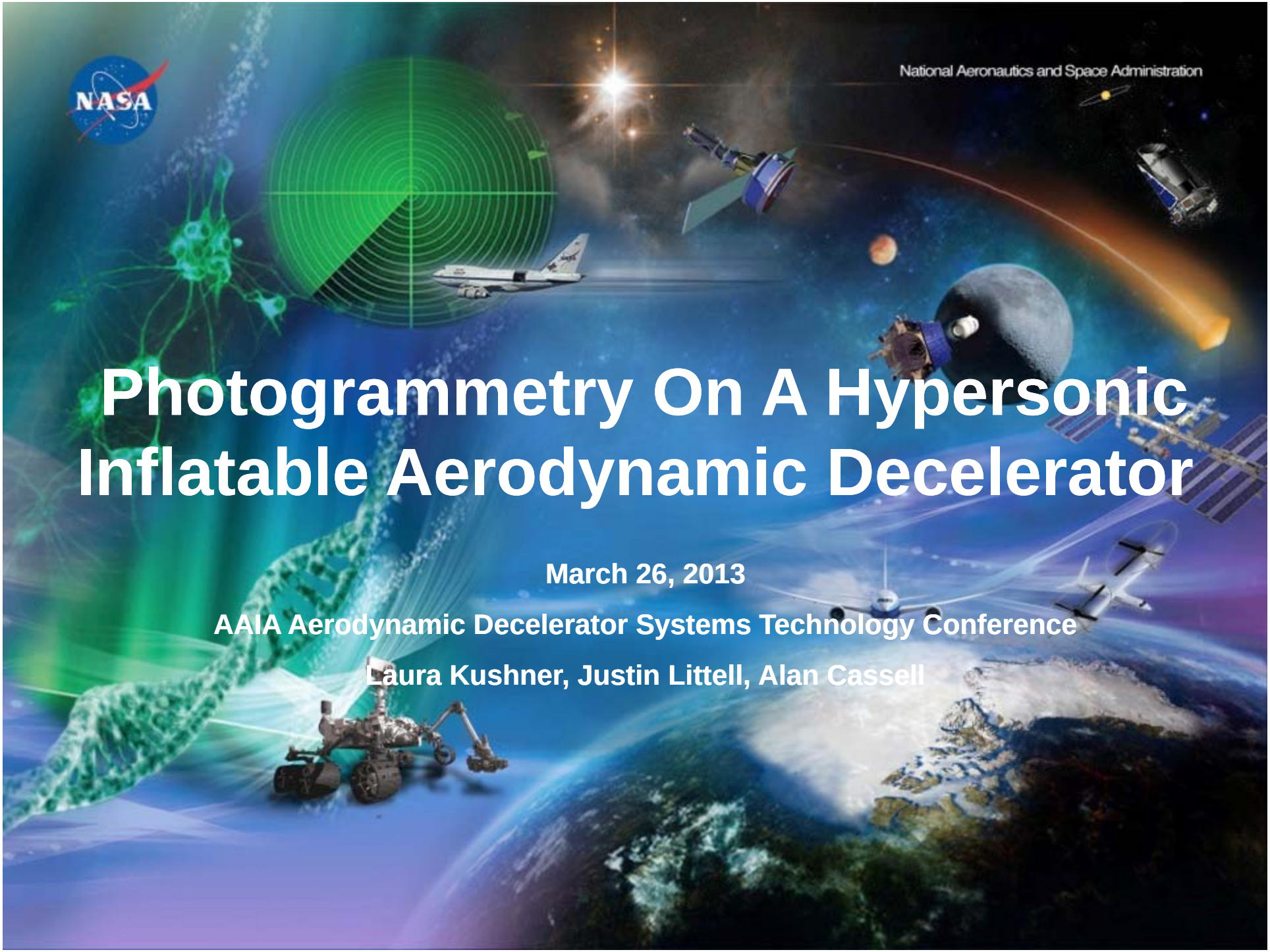



# Photogrammetry On A Hypersonic Inflatable Aerodynamic Decelerator

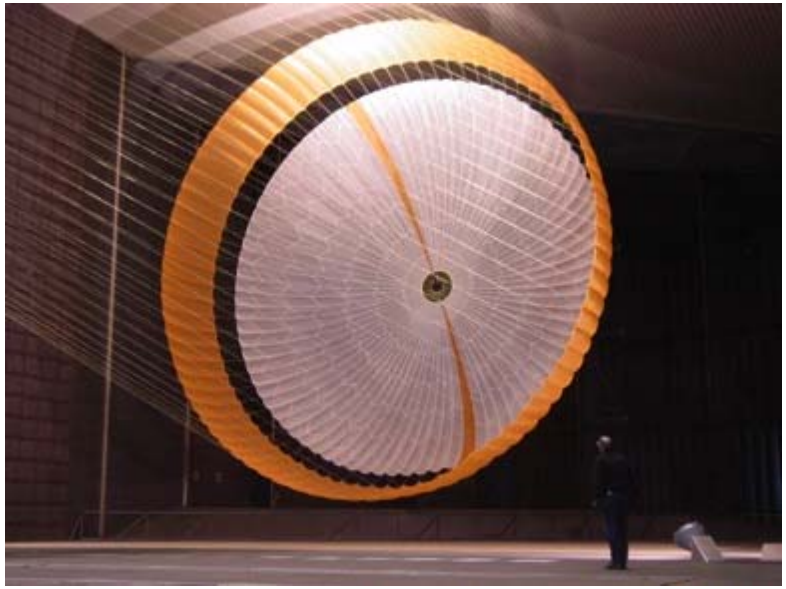
March 26, 2013

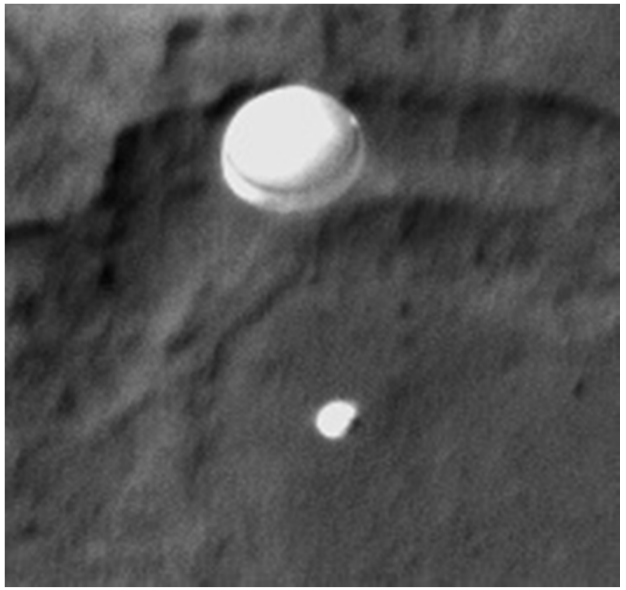
AAIA Aerodynamic Decelerator Systems Technology Conference

Laura Kushner, Justin Littell, Alan Cassell

# HIAD/Decelerator Overview

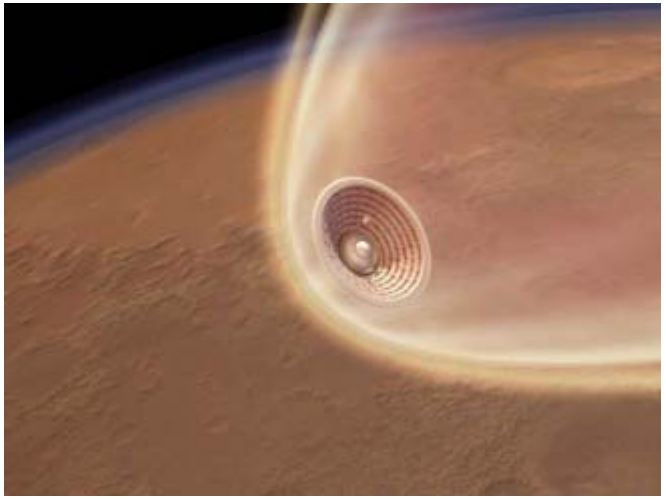
- Current Entry Decent and Landing Technology: Disk Gap Band Parachutes and rigid Thermal Protection Systems (TPS)
  - 1.5 metric ton limit on Mars
- New methods of landing higher masses on bodies with thin atmospheres are needed.





# HIAD/Decelerator Overview

- One option: Inflatable Aerodynamic Decelerators (IADs)
- HIAD – Hypersonic IAD
  - Deployed before atmosphere
    - Controlled and longer deceleration
  - Mass/volume savings
  - Diameters unconstrained by launch vehicles
- HIAD Project
  - Stacked Toroid, spherical nose cone, flexible TPS
  - Ground Test Program
    - Improve and verify HIAD performance
    - Measure surface deflection
      - Photogrammetry

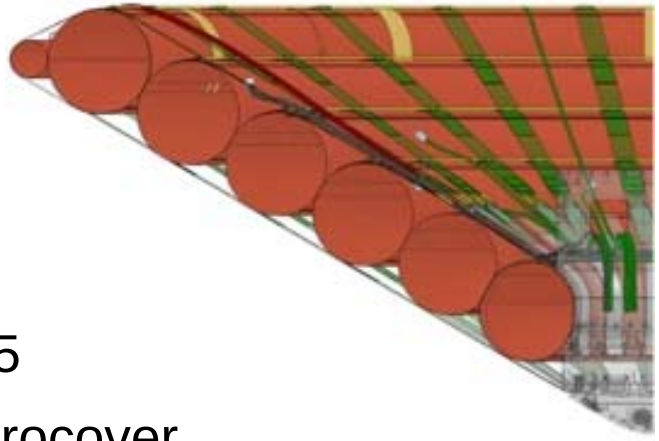


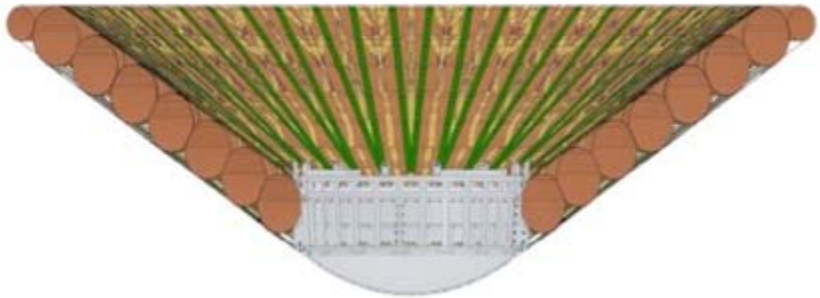
# National Full-scale Aerodynamics Complex (NFAC)

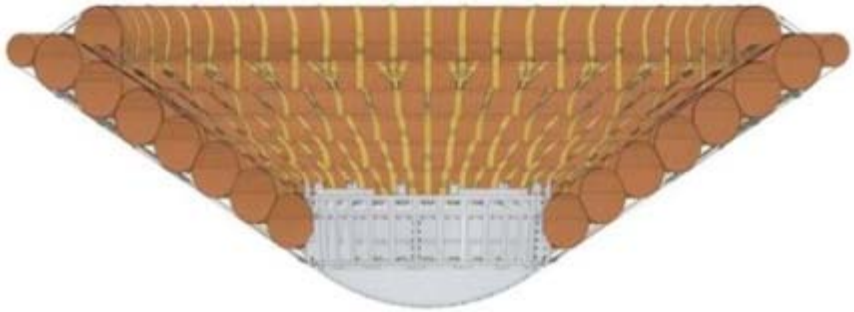
- 40- by 80- foot test section
- Acoustically lined
  - Limited optical access

# HIAD Models

- 2 Stacked Toroid models
  - 6-meter
  - 3-meter
- 60 degree half-angle
- 2 configurations
  - 6-meter: with and without torus T6.5
  - 3-meter: with a TPS and flexible aerocover

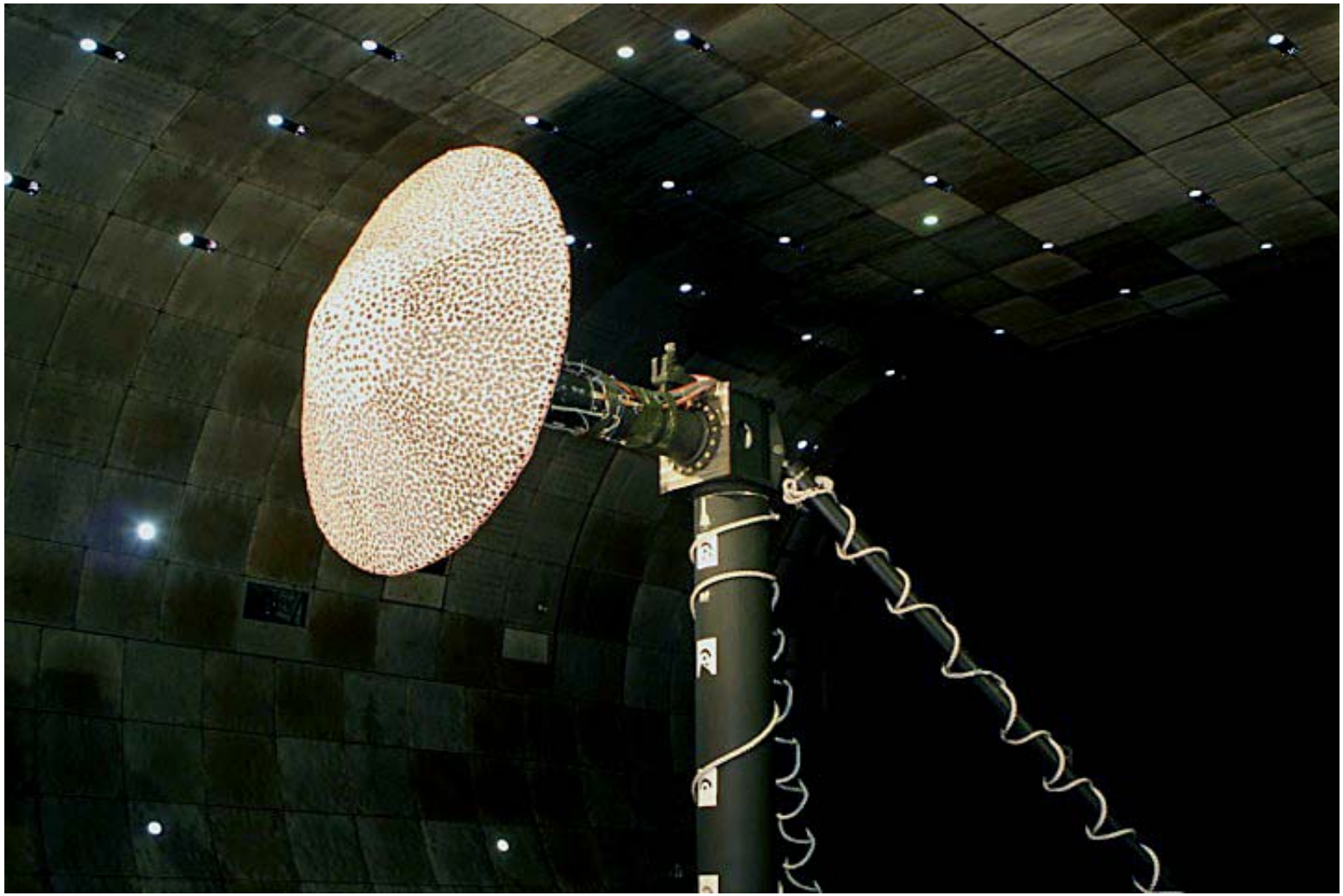






# 6-meter HIAD Test Article in the 40- by 80- foot Test Section

# 3-meter HIAD Test Article in the test section, with TPS



# Photogrammetry

- Optical method for measuring the spatial coordinates of points on an object.
- Two or more cameras are used to image a Region of Interest (ROI) on a model.
- Cameras calibrated by imaging an object with targets of known spacing.
- Spatial coordinates located from image-plane coordinates and camera coefficients determined during calibration.
- Targets or speckles

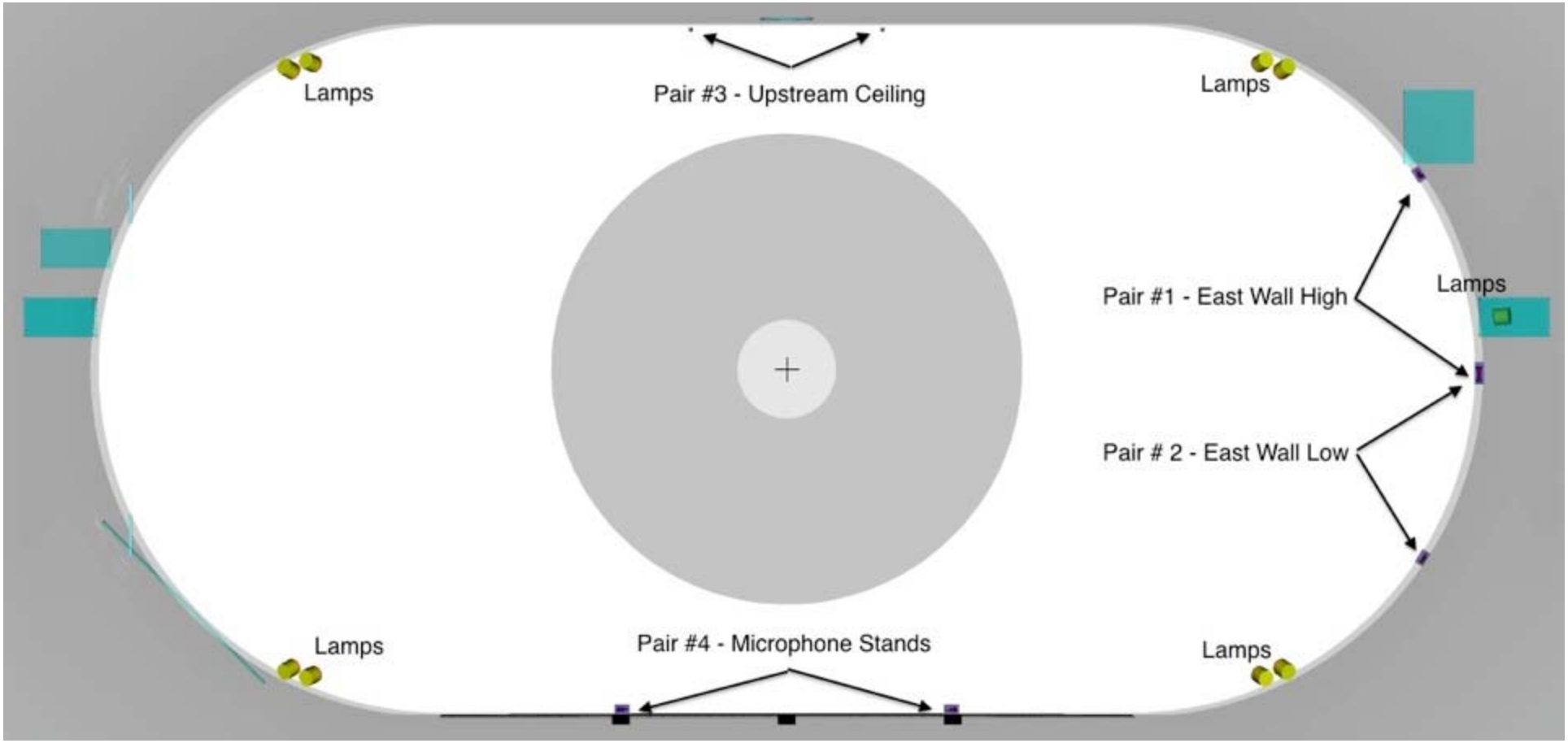
- Requirements:
  - Measure entire front face of 8.5 meter model
  - Full range of model attitudes

# Photogrammetry Setup Design

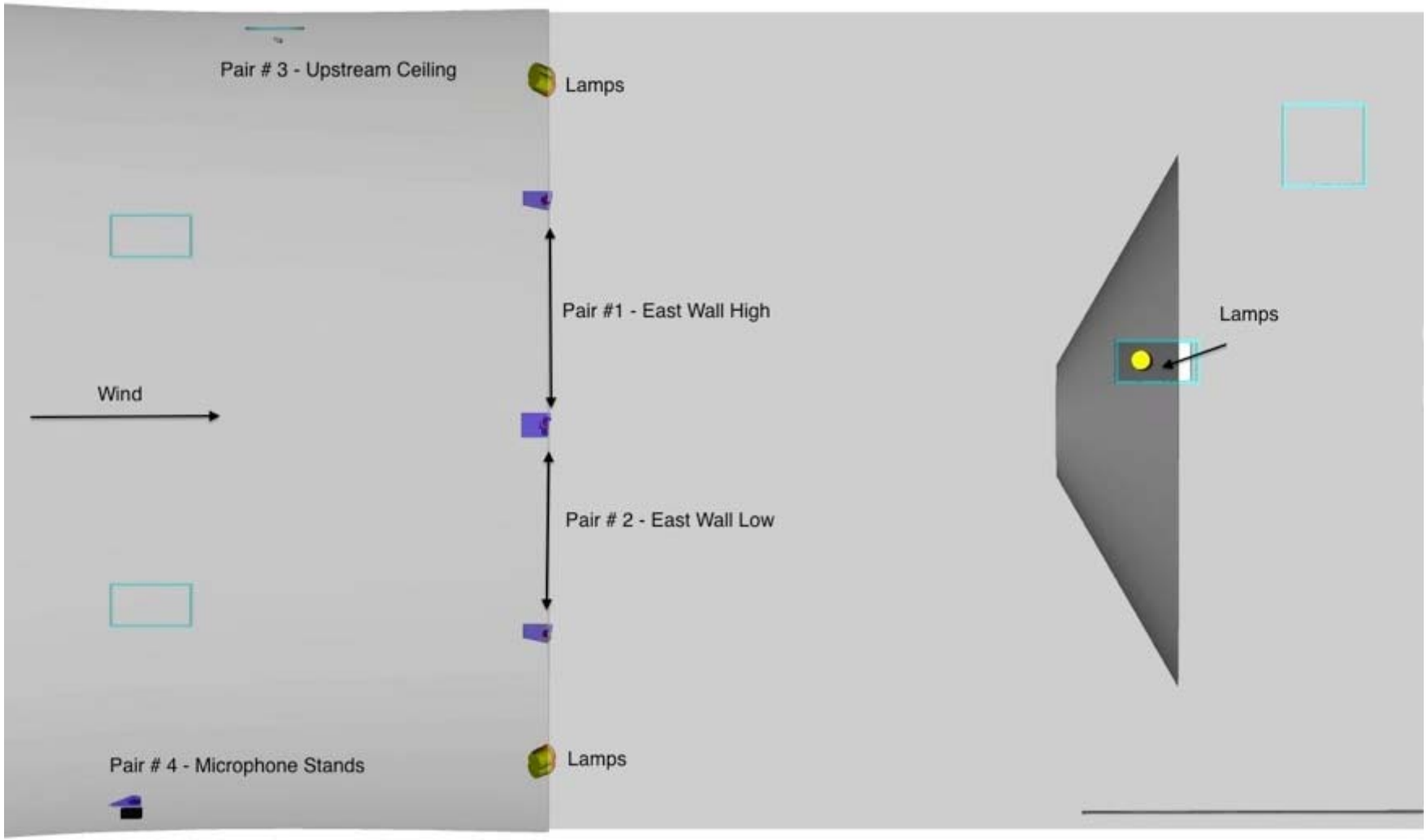
- Commercial system adapted to make measurements
  - ARAMIS 5M by GOM
    - Tabletop photogrammetry system-- analysis immediately after acquisition
    - 2 cameras
      - 5 megapixel, 3.45 micron pitch
      - 15 Hz
    - Rigid mounting bar
      - 15 to 25 degree convergence angle
      - Software assumptions add additional constraints

- Extensive system design to adapt to Production Environment
  - Virtual Imaging to optimize camera placement
  - Custom data flow scripts to adapt to production testing
  - Full coverage requires 4 ARAMIS 5M systems

# Virtual System Setup in the NFAC – Upstream View



# Virtual System Setup in the NFAC – Side View



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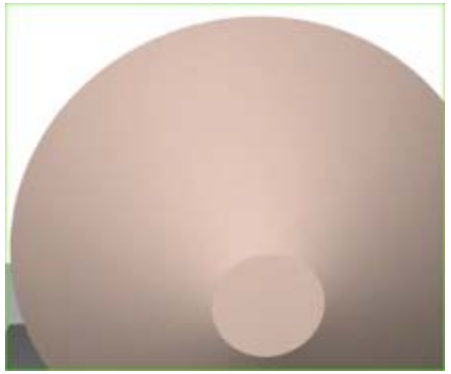
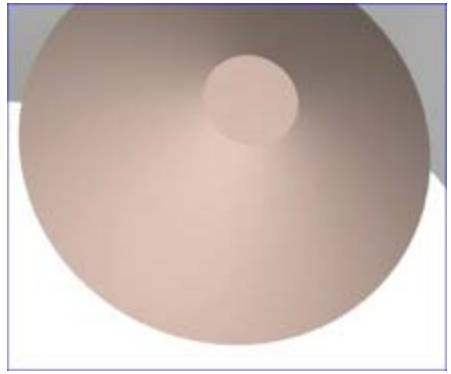
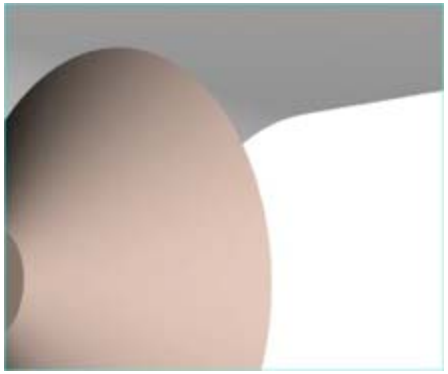
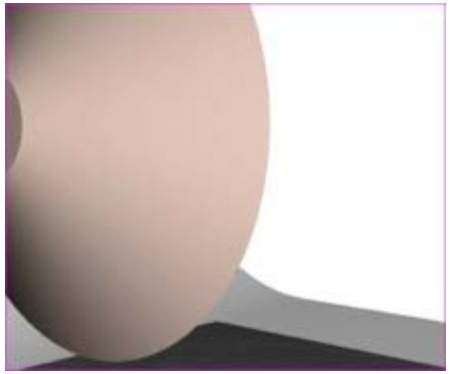
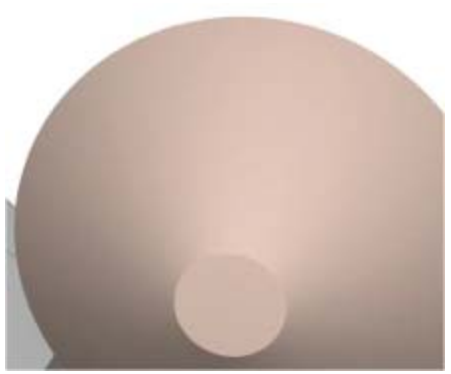
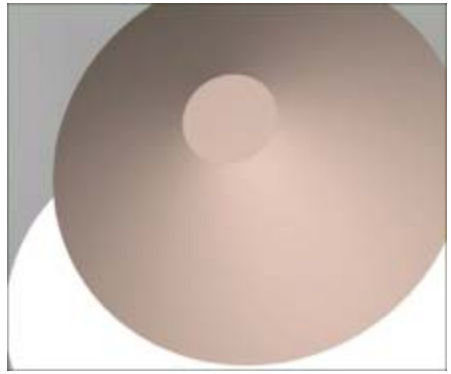
# Predicted Camera Views – Yaw: 0 degrees



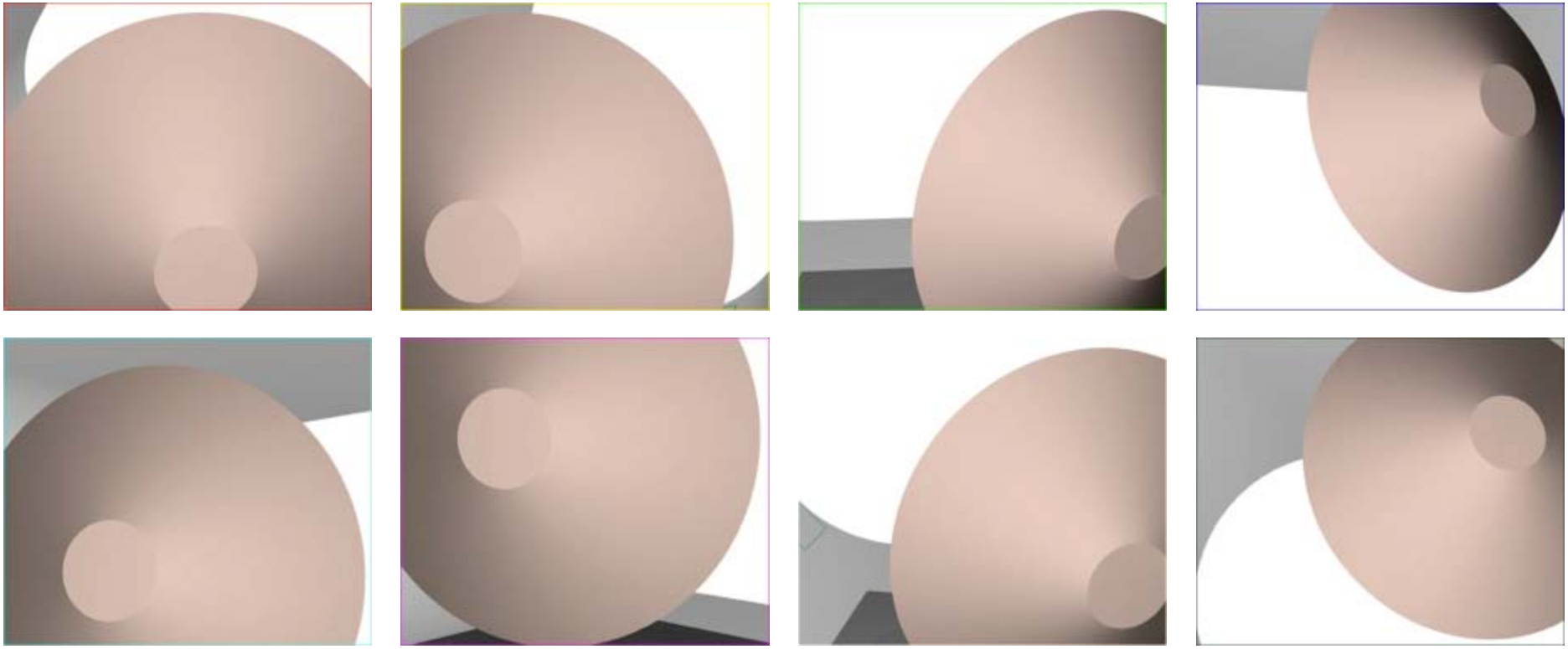
**Pair 1**
East High

**Pair 2**
East Low

**Pair 3**
Upstream Ceiling

**Pair 4**
Microphone Stands

# Predicted Camera Views – Yaw: -25 degrees



**Pair 1**
East High

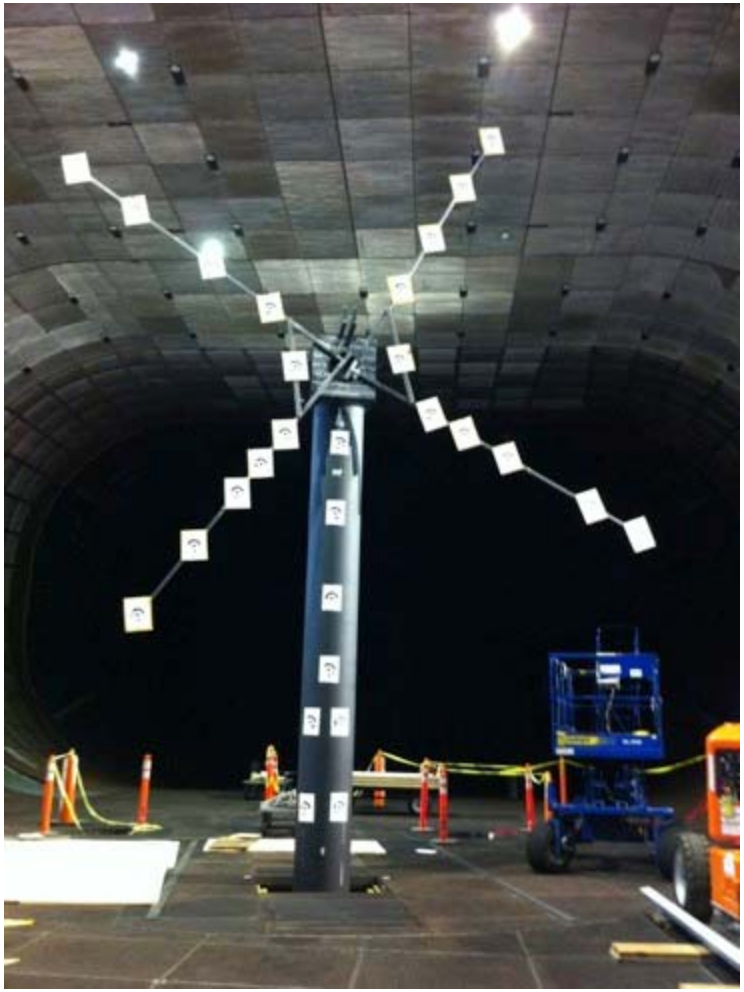
**Pair 2**
East Low

**Pair 3**
Upstream Ceiling

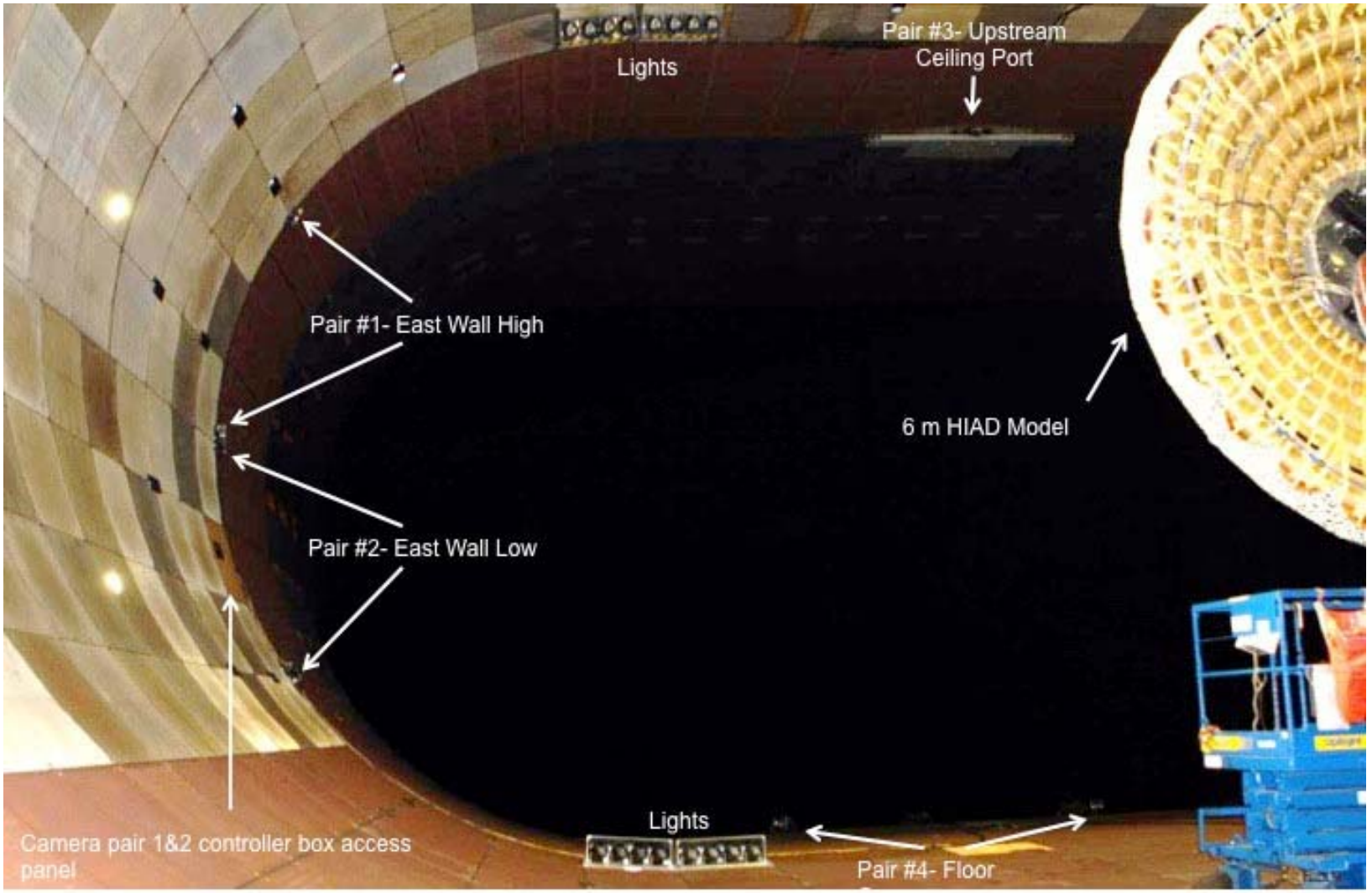
**Pair 4**
Microphone Stands

# Calibration

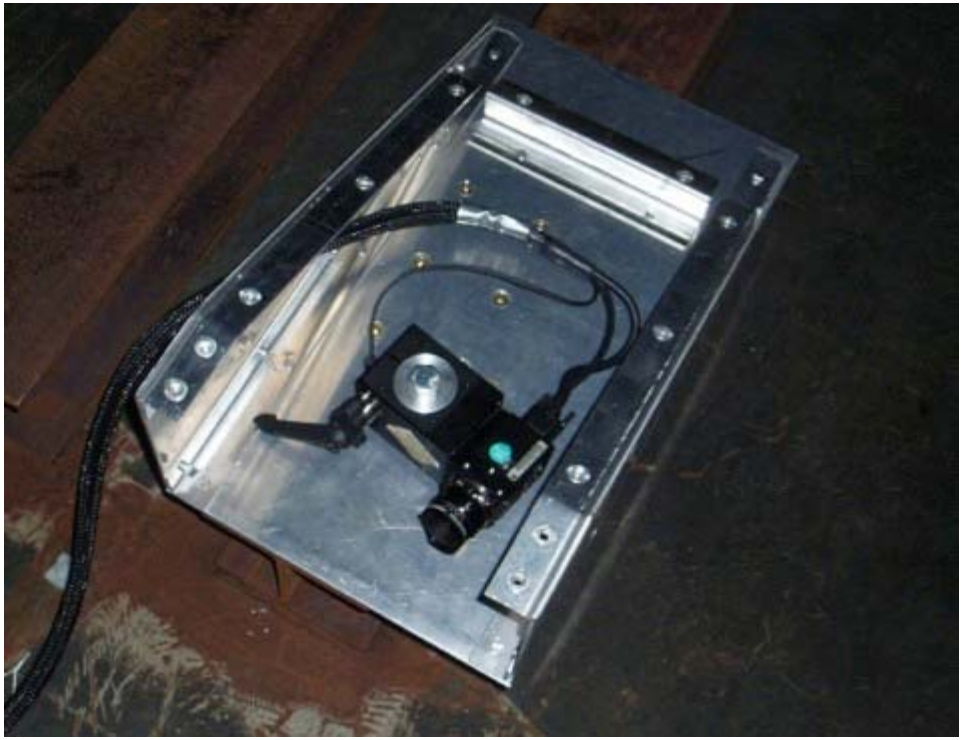
- ROI: 40 ft. x 30 ft. x 30 ft.
- No suitable calibration object
- Create calibration cross
  - 20 coded targets
  - Targets located with a commercial photogrammetry system, calibrated with a known calibration object
- Large Area Calibration – Reverse Logic
  - Move the cameras instead of the cross
  - Lens distortion: rotate cameras
  - Span measurement volume: reposition cameras throughout test section



# Camera Installation



# Camera Installation – Microphone Stands



# Camera Installation – Ceiling Dome and East Wall


# Targets

- 3 and 5 pixels
- 0.75 and 1.25 inches in diameter
- 6-meter: printed directly to aerocover
- 3-meter: hand-stamped with ink

| Model | Spatial Resolution (pixels/inch) |
|---|---|
| 3-meter | 4 to 9 |
| 6-meter | 6 to 13 |
| 8-meter | 5 to 13 |

# Illumination

- 34 Sourcefour Par EA-A theater lamps
  - 750 Watts
  - Tungsten
  - 20 degree Fresnel lens

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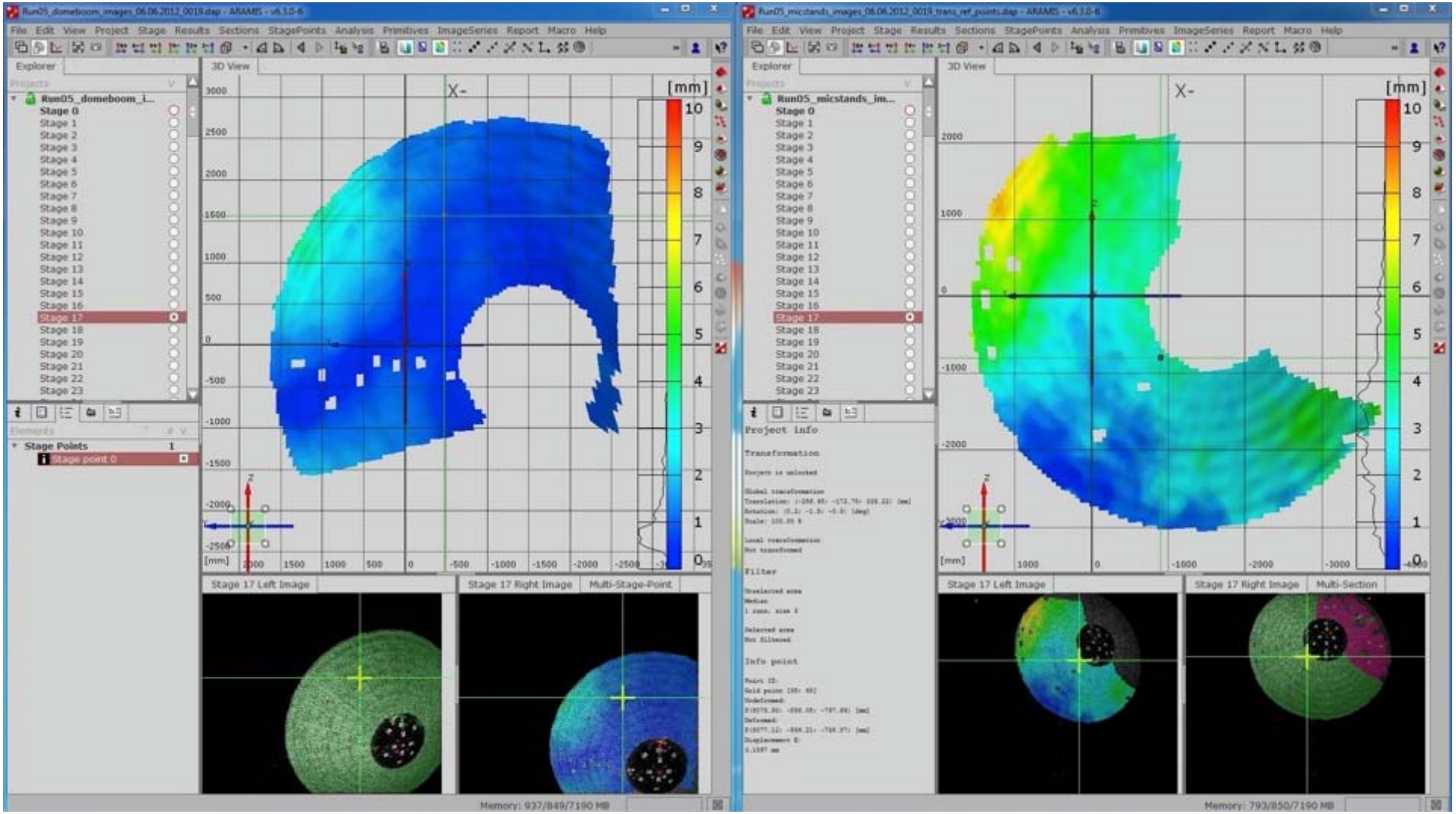
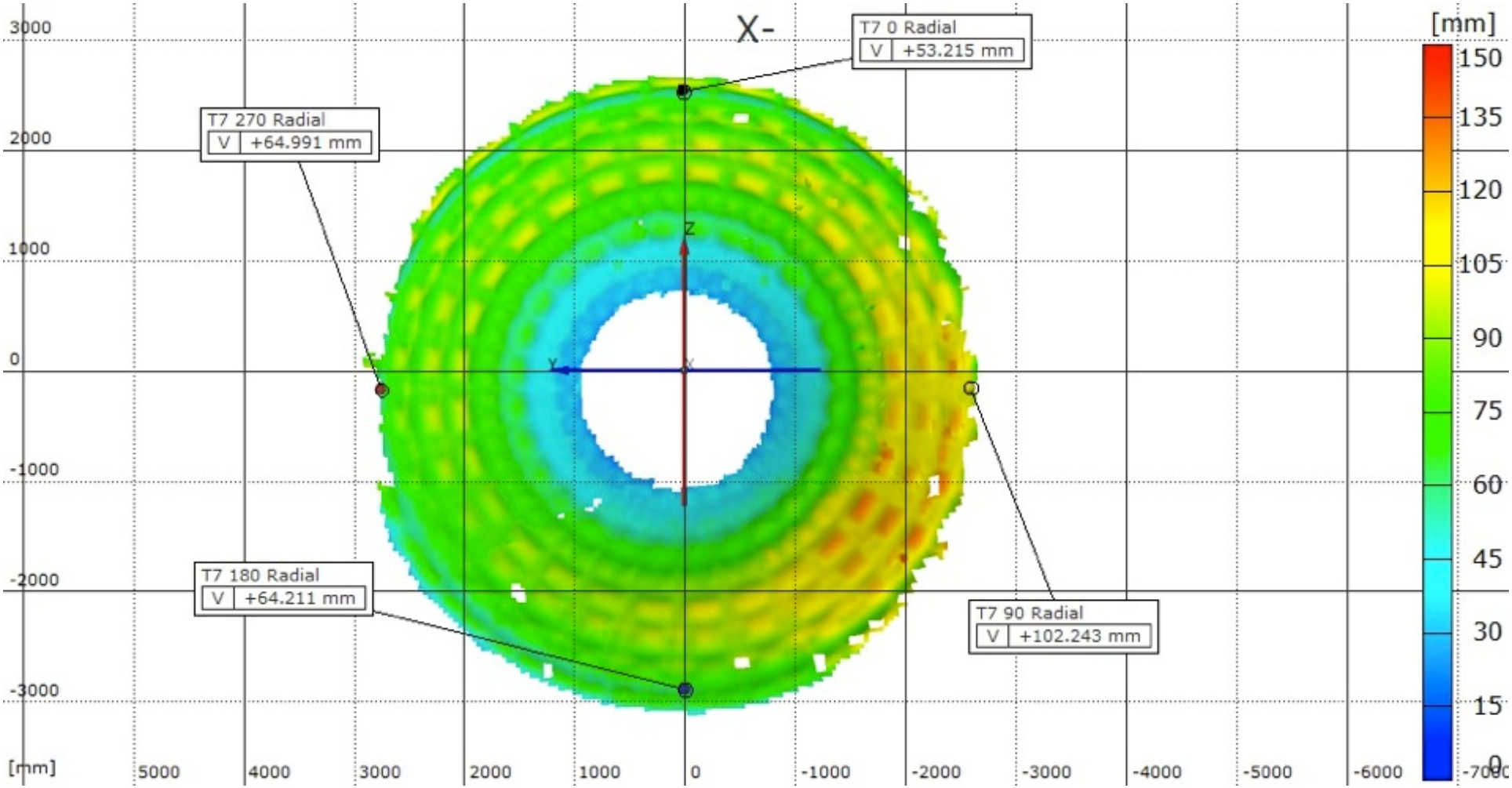
# Quick Look Data



# Stitched Data



# Summary

- Two large-scale HIADs were successfully tested.
- The main objective of measuring model deflections under aerodynamic loading that approximated expected flight conditions with stereo photogrammetry was met.
- Four commercial ARAMIS 5M photogrammetry systems were successfully adapted to measure the deformation of HIAD.
- The data will be used for comparisons to and refinement of Fluid Structure Interaction models.


- Image Credits:
  - NASA/JPL-Caltech
  - NASA Ames Research Center
  - Alan Cassell
  - Justin Littell