Photogrammetry On A Hypersonic Inflatable Aerodynamic Decelerator

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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
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

<table>
<thead>
<tr>
<th>Model</th>
<th>Spatial Resolution (pixels/inch)</th>
</tr>
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<tbody>
<tr>
<td>3-meter</td>
<td>4 to 9</td>
</tr>
<tr>
<td>6-meter</td>
<td>6 to 13</td>
</tr>
<tr>
<td>8-meter</td>
<td>5 to 13</td>
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Illumination

- 34 Sourcefour Par EA-A theater lamps
  - 750 Watts
  - Tungsten
  - 20 degree Fresnel lens
Quick Look 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:
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  • Alan Cassell
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