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

- Pair #3 - Upstream Ceiling
- Pair #1 - East Wall High
- Pair #2 - East Wall Low
- Pair #4 - Microphone Stands
- Lamps
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>
</thead>
<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
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
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  • Alan Cassell
  • Justin Littell