



# **Photogrammetry at the Landing and Impact Research Facility at NASA Langley Research Center**

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NASA Langley Research Center

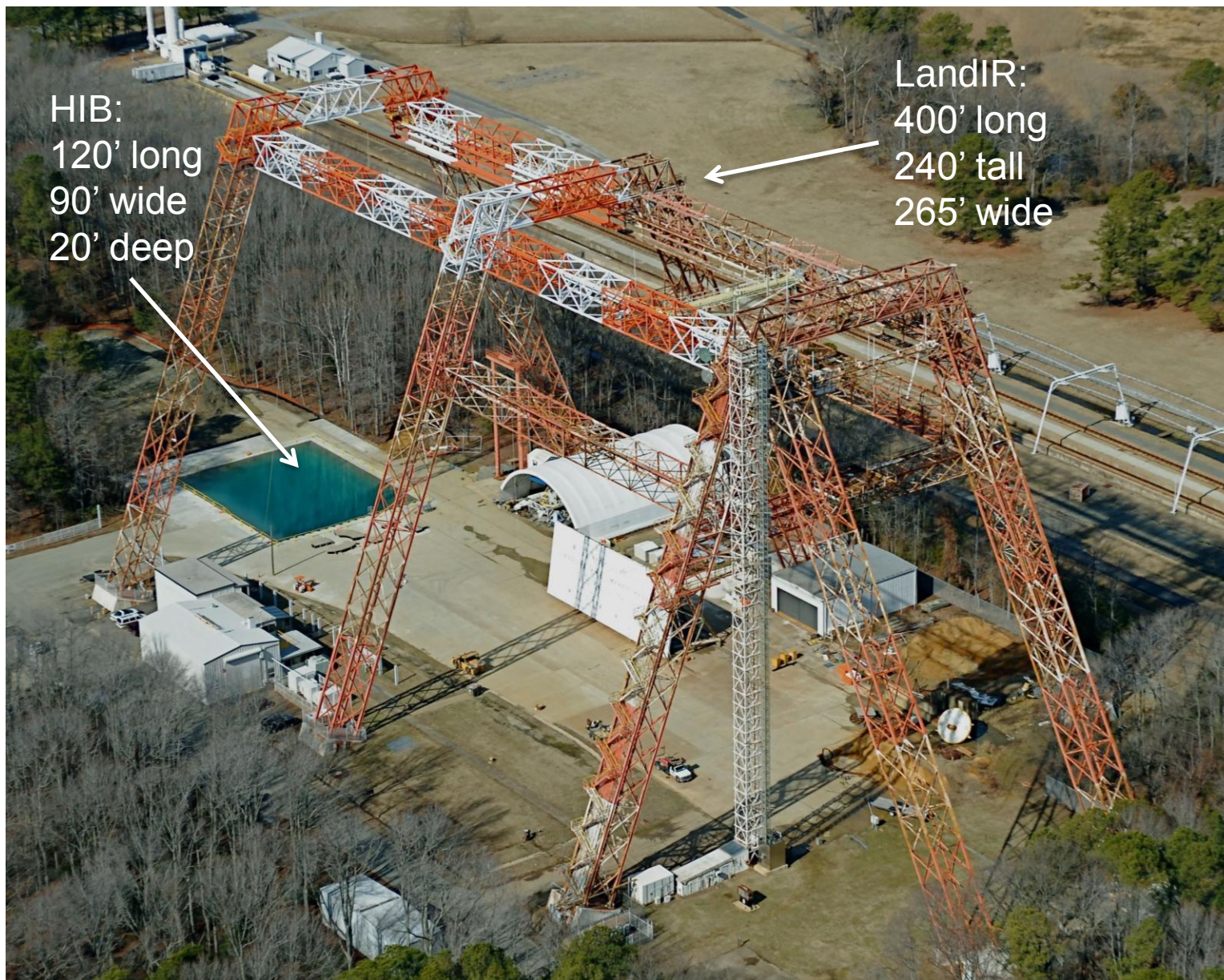
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Trillion User Group Conference Keynote Lecture

25 Sept 2012



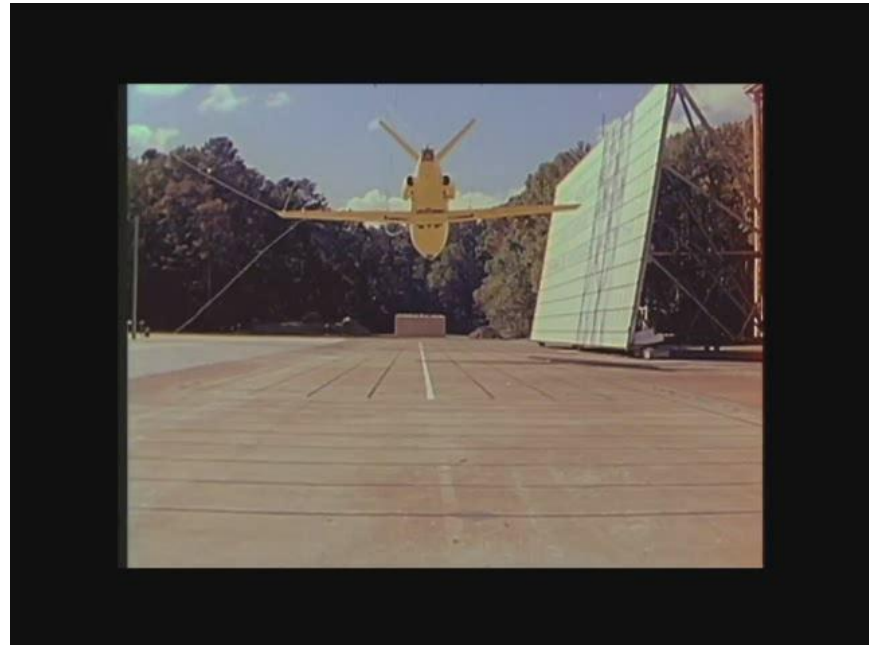
# Landing and Impact Research Facility (LandIR)





# LandIR background

- 1965 - Lunar Lander training site
- 1970s – 2000s - Aircraft crash facility
  - GA, military airplanes and helicopters
- 2003 - Orion landing tests
- 2010 - Hydro Impact Basin built





# Presentation outline

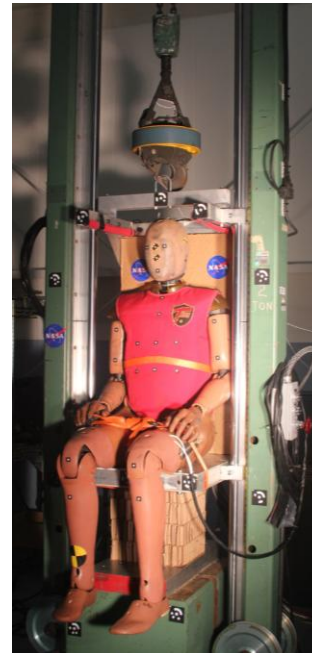
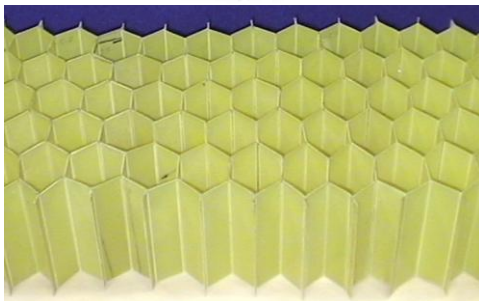
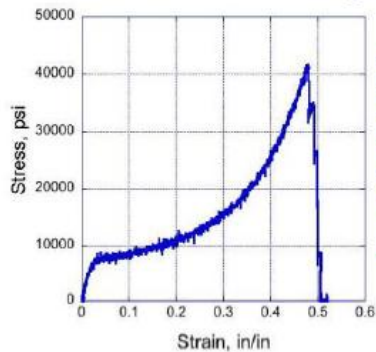
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- Background
- Introduction/Setup/Challenges
- Aircraft
  - Materials testing
  - Composite research
  - MD-500 impact test comparisons
  - Anthropomorphic Test Device (ATD) testing
- Spacecraft
  - Composite Crew Module
  - Orion half-scale
  - Orion Boilerplate Test Article water landing
  - STS-133 – External Tank stringer crack investigation \*
  - STS-133 – Ground Umbilical Carrier Plate leak investigation \*
  - Hypersonic Inflatable Aero Decelerators \*



# Current LandIR Research

- Unique facility allows for the testing of items from coupons to airframes
  - Composites, metals, honeycombs, foams, struts, ATDs,
  - MD-500, CH 46, Orion Boilerplates, Orion Pallets, “Iron Birds”
- I put dots on everything!





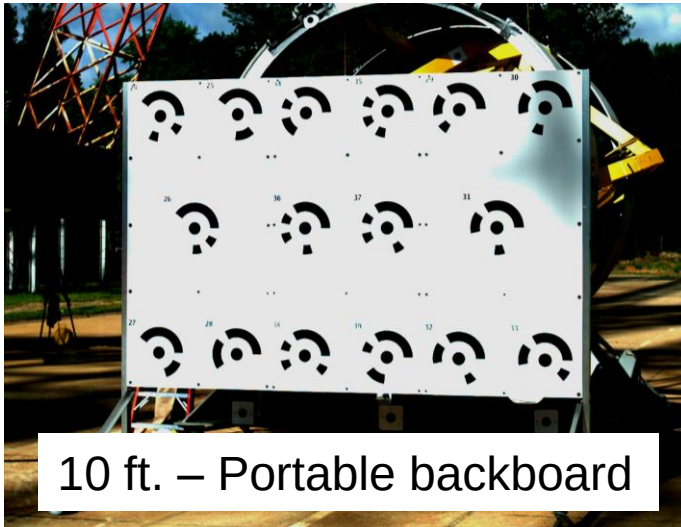
# Photogrammetry background at LandIR

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- Range from 2 cm to ~50ft FOVs
  - Areas above 2 m, large area method is used
- **PONTOS** – discrete target tracking for vehicle impact conditions, ATD motion
- **ARAMIS** – strain mapping for vehicle, materials, component deformations
- **SVIEW** - stitching of multiple ARAMIS camera views
- **TRITOP** - large field calibrations and the generation of point clouds



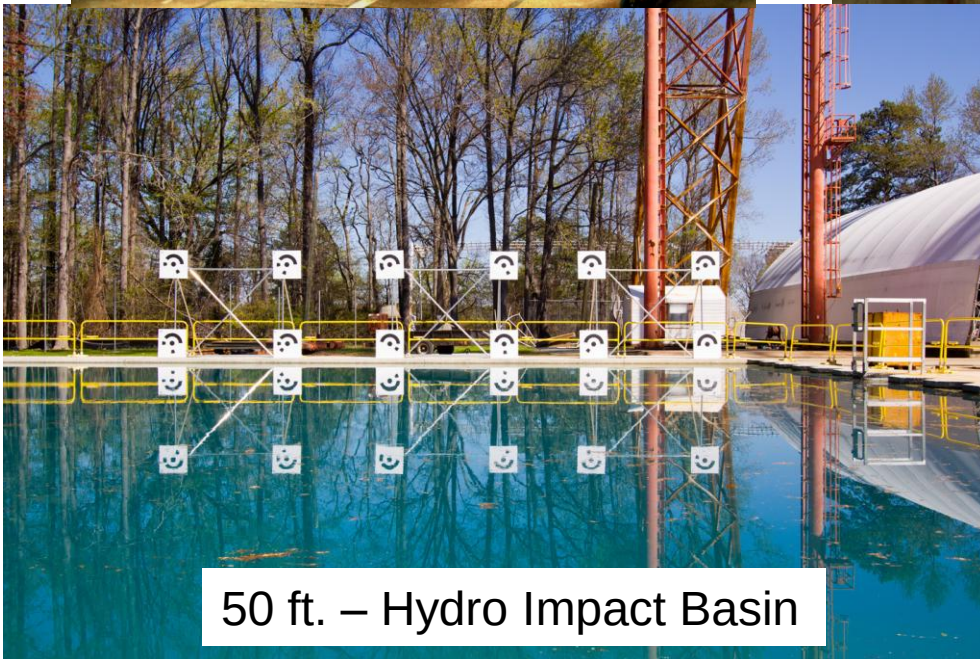
# Calibration hardware



10 ft. – Portable backboard



50 ft. – Large backboard

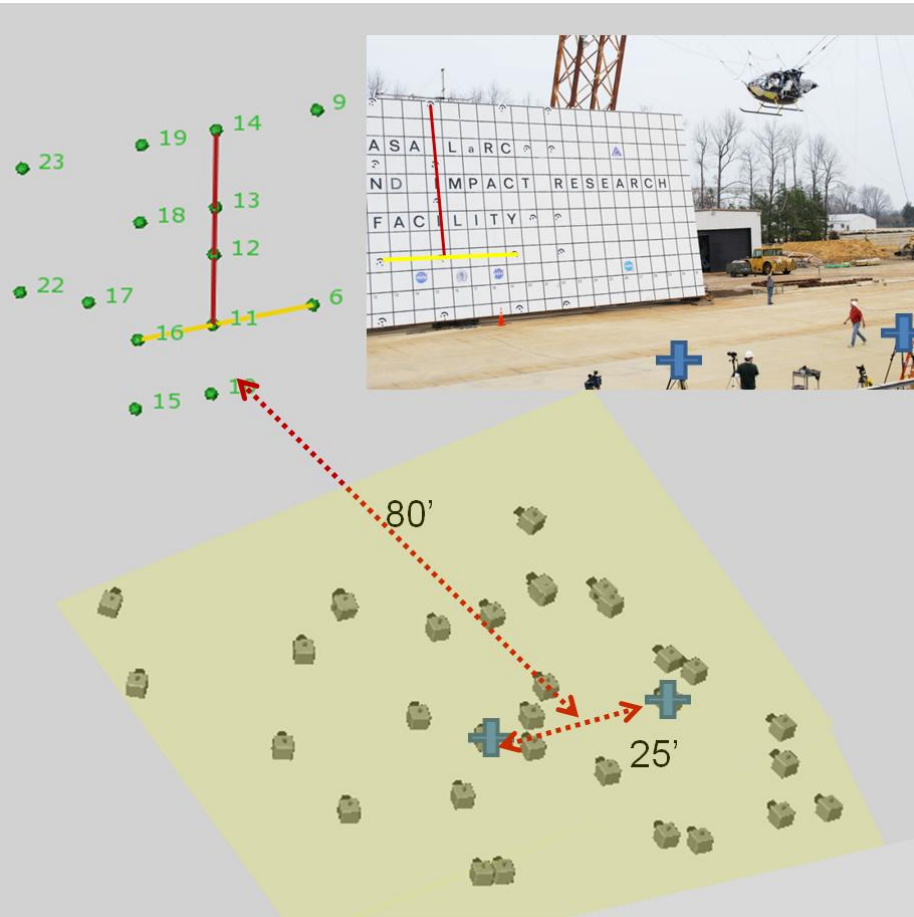


50 ft. – Hydro Impact Basin

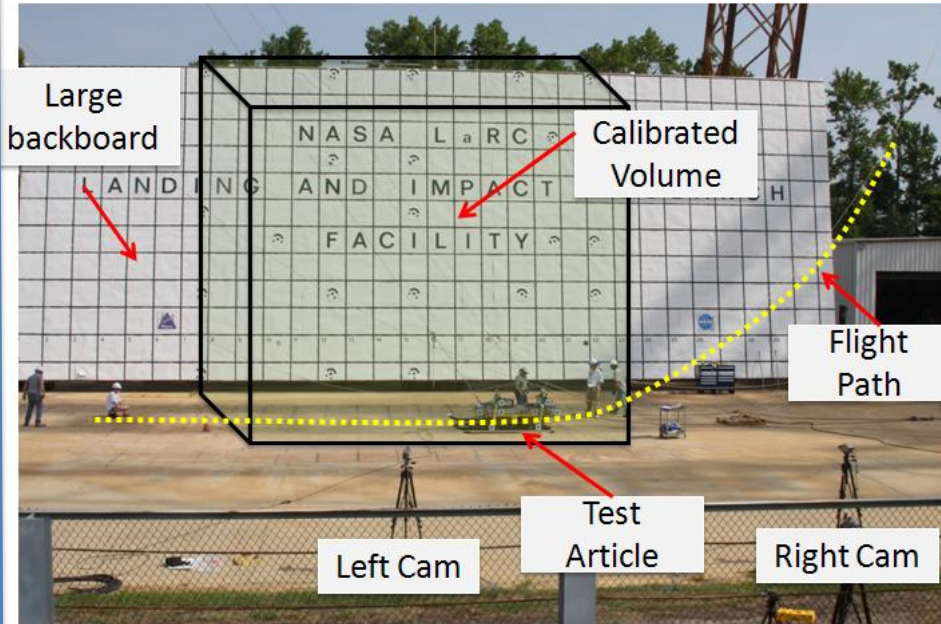




# Calibration procedures and typical setup

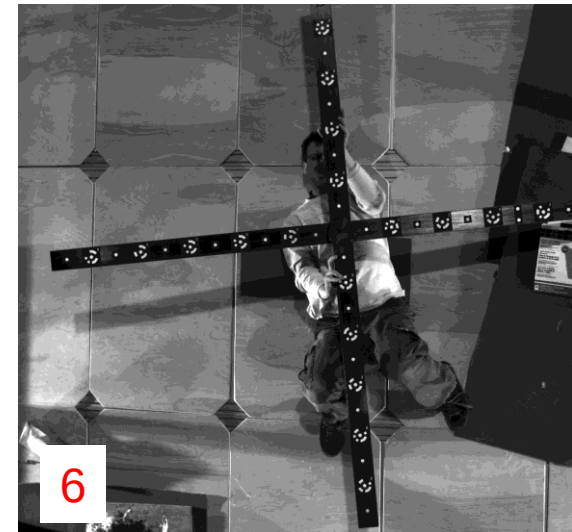
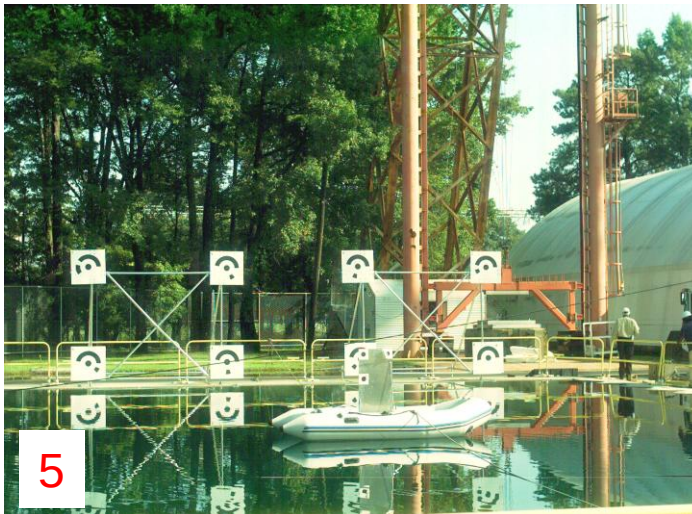
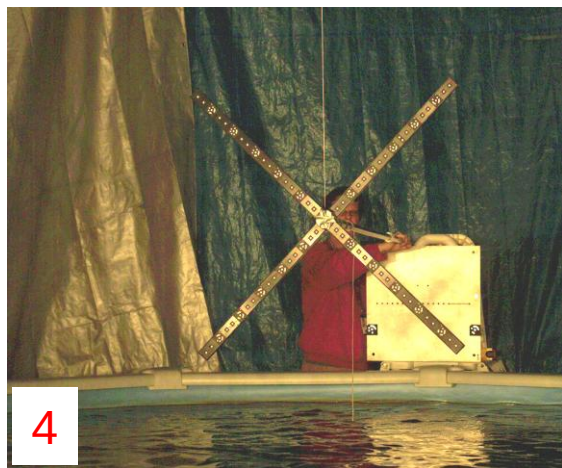
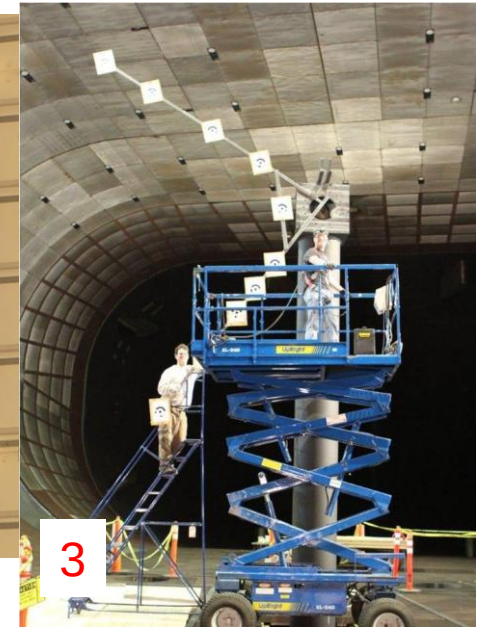


- Phantom 9 cameras
- 1632 x 1200
- 1000 fps
- 24mm focal length lenses



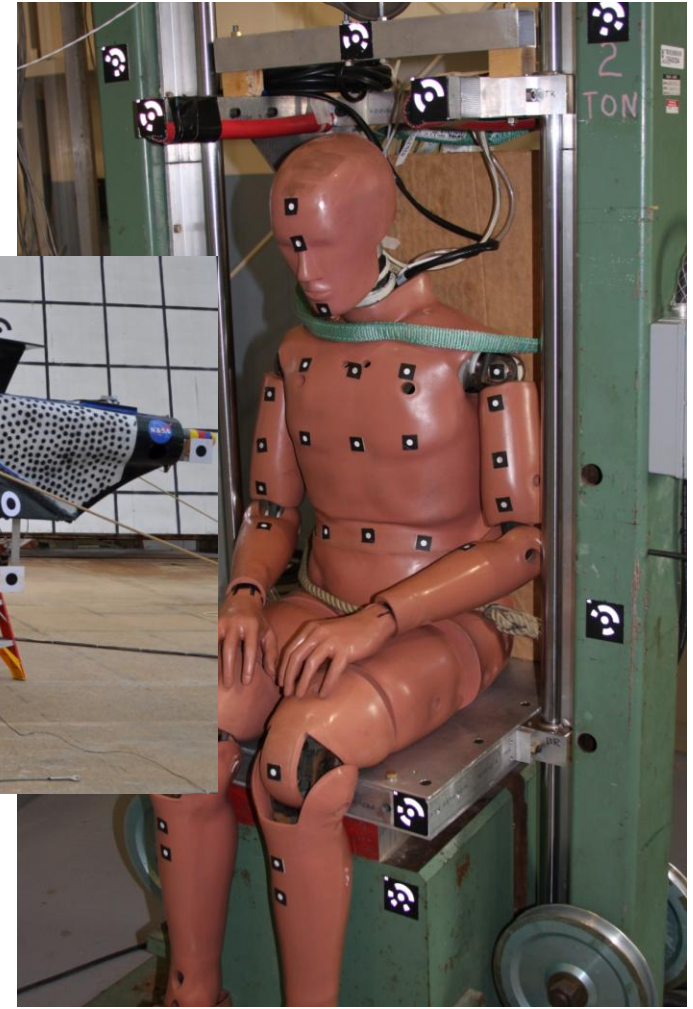
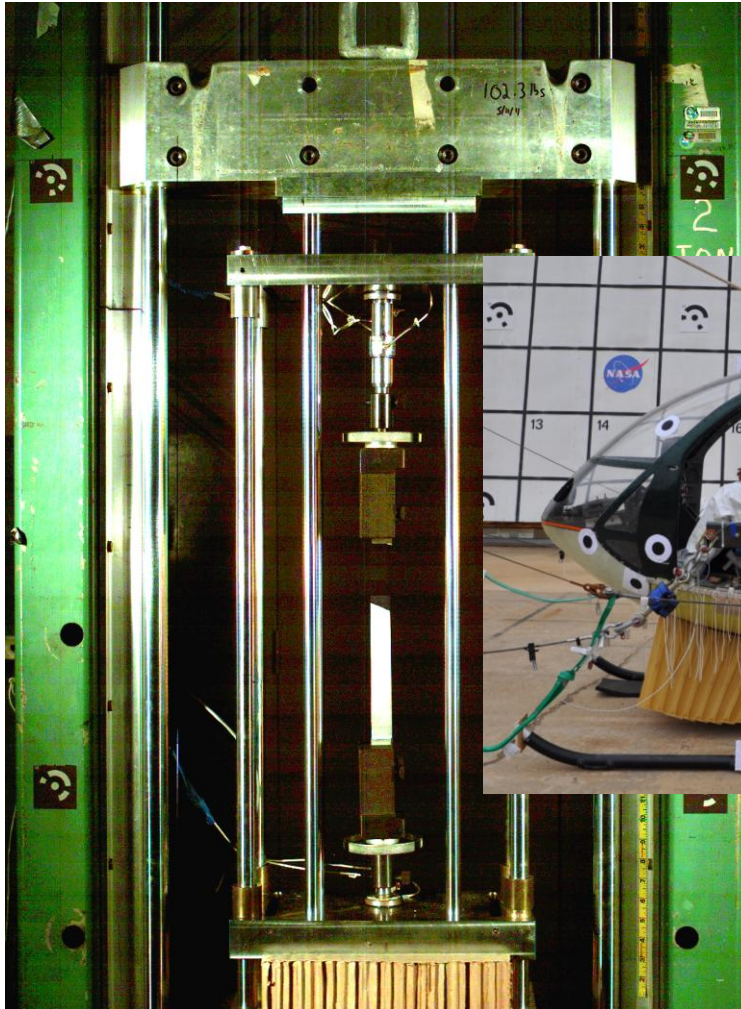
- Field of view is approximately 30 - 60 feet, depending on test
- Cameras capture final few seconds of free fall and then impact

# Challenges – “We’re not in a laboratory”





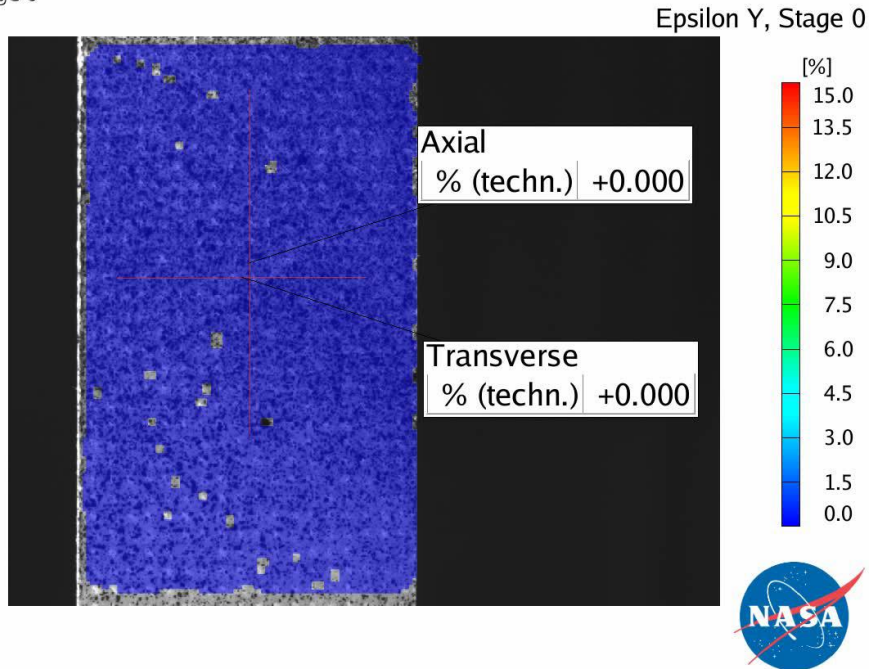
# NASA Aircraft Photogrammetry Applications



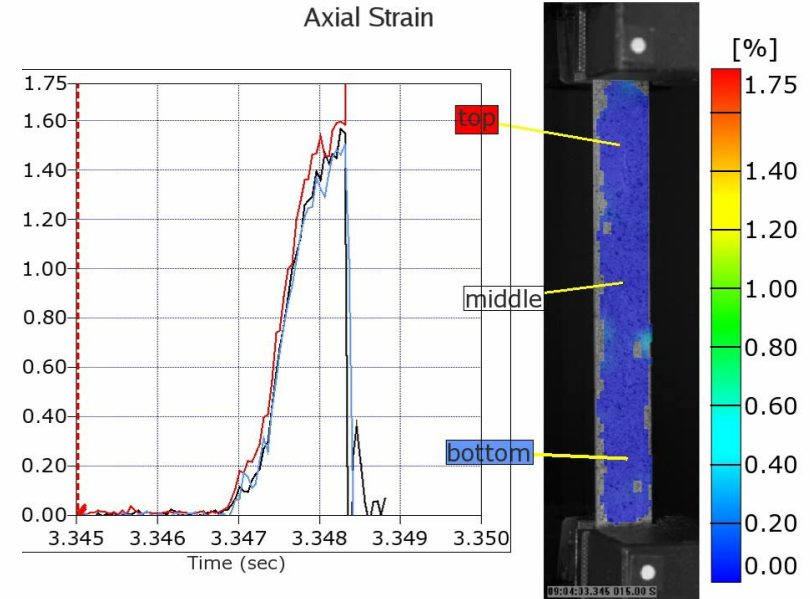


# Materials Research

Stage 0



Static Materials Tensile Test

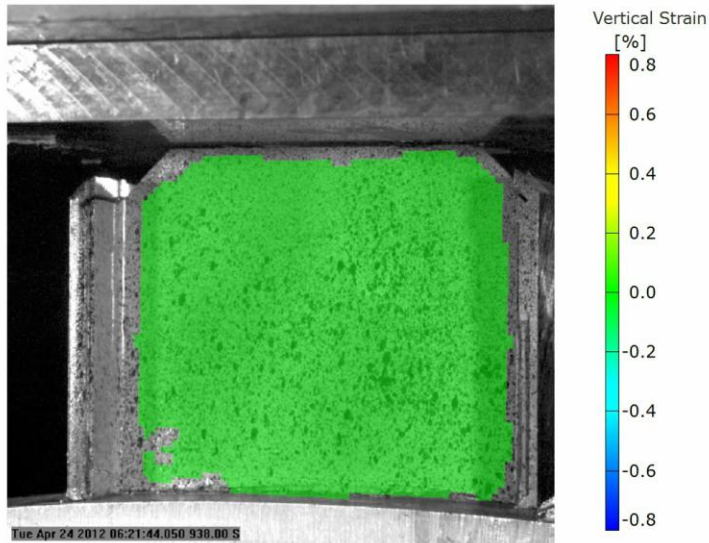


Dynamic Materials Tensile Test

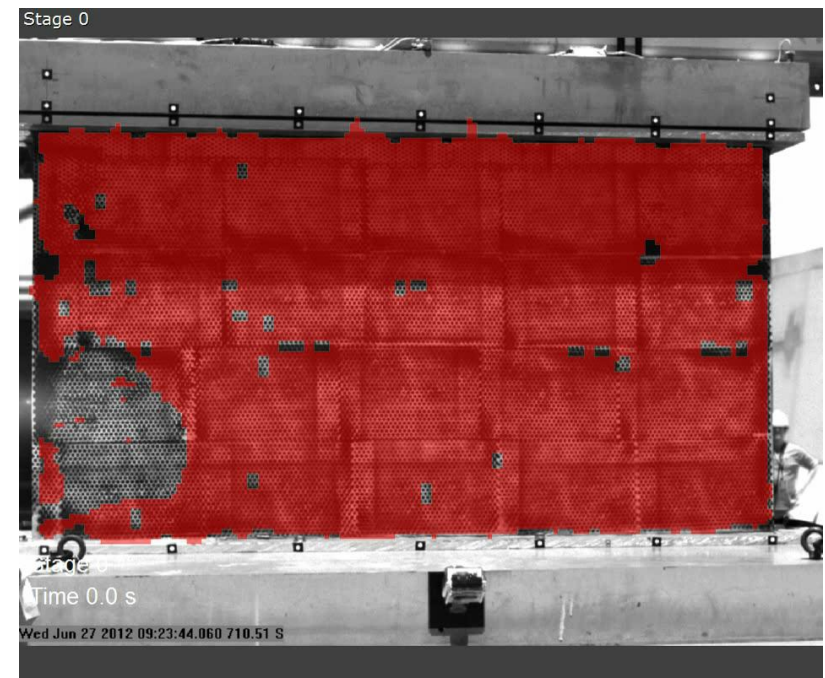
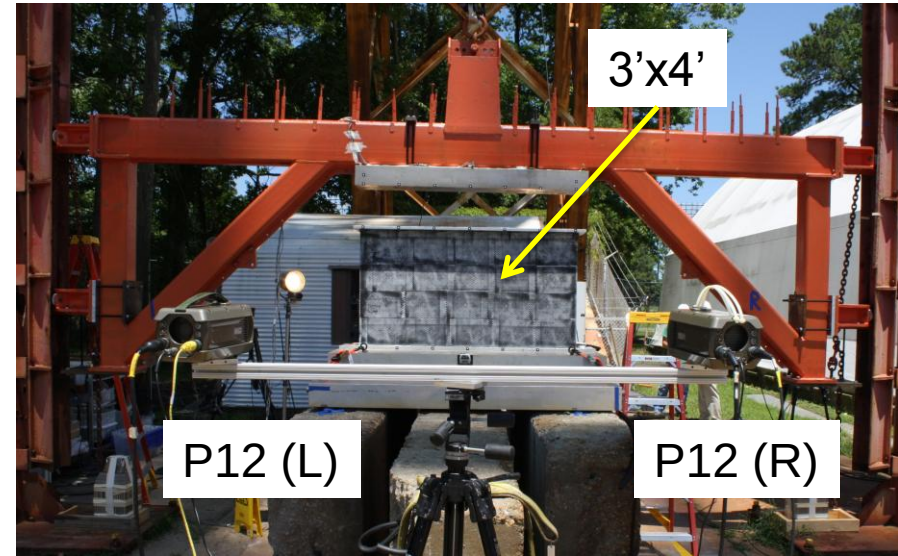
- Research many types of energy absorbing structures including composites, foams, metals and other exotic materials



# Composite components

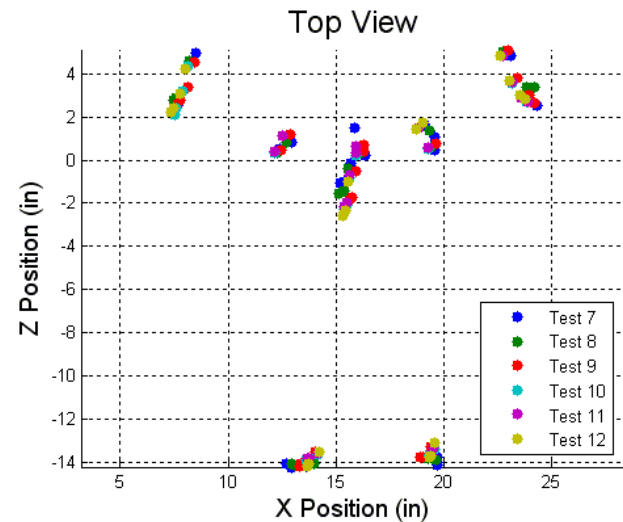
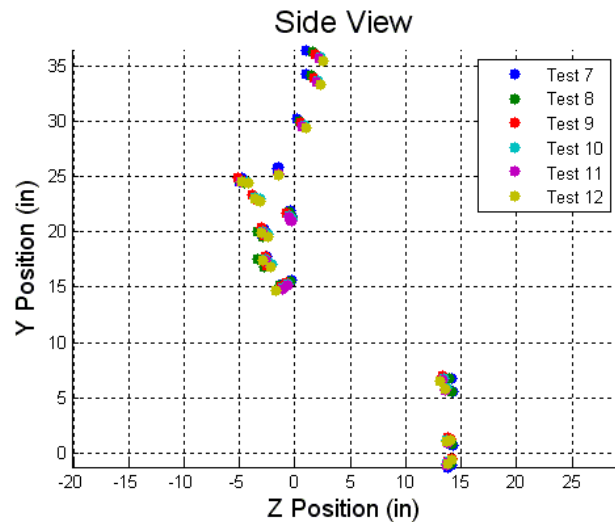
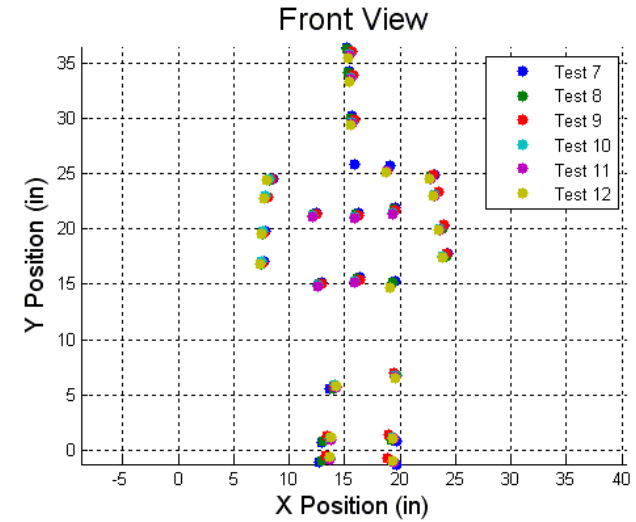
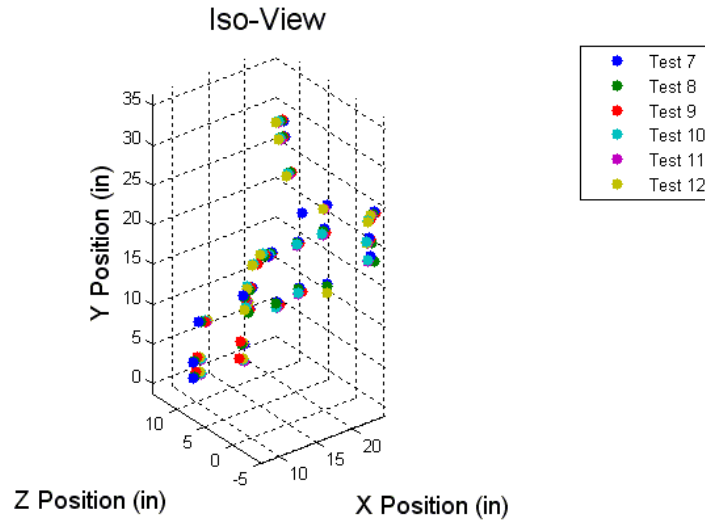


- I-beam (above) is used in the supporting structure for the floor (right)
- 10 kHz filming rates are needed due to the fast development of deformation in these composites





# ATD testing - Positioning





# MD-500 tests

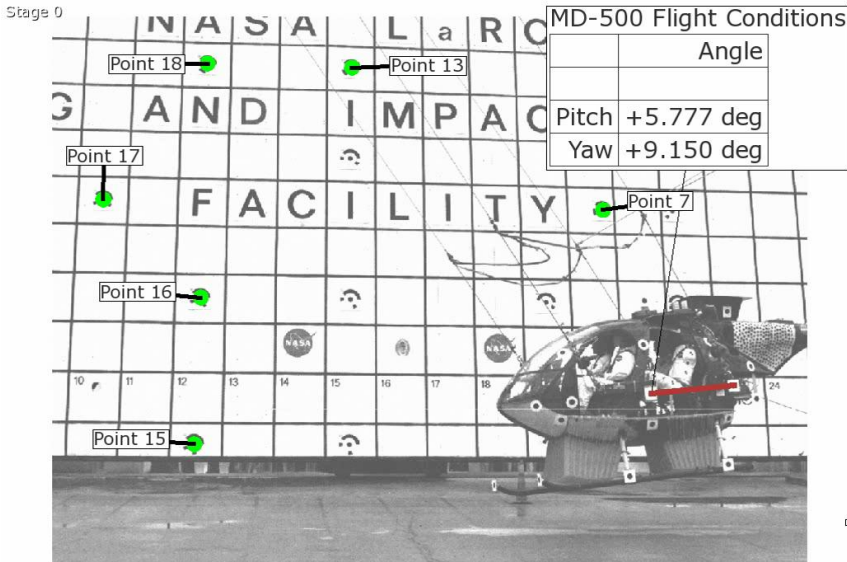
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# MD-500 - Impact conditions and lesson learned

| Impact Parameter      | MD-500 with DEA | MD-500 without DEA |
|-----------------------|-----------------|--------------------|
| Linear velocity (fps) |                 |                    |
| Forward               | 38.8            | 39.1               |
| Vertical              | 25.6            | 24.1               |
| Lateral               | 0.5             | 0.6                |
| Attitude (deg)        |                 |                    |
| Pitch                 | -5.69           | -6.2               |
| Roll                  | 7.04            | 1.9                |
| Yaw                   | 9.3             | 2.1                |

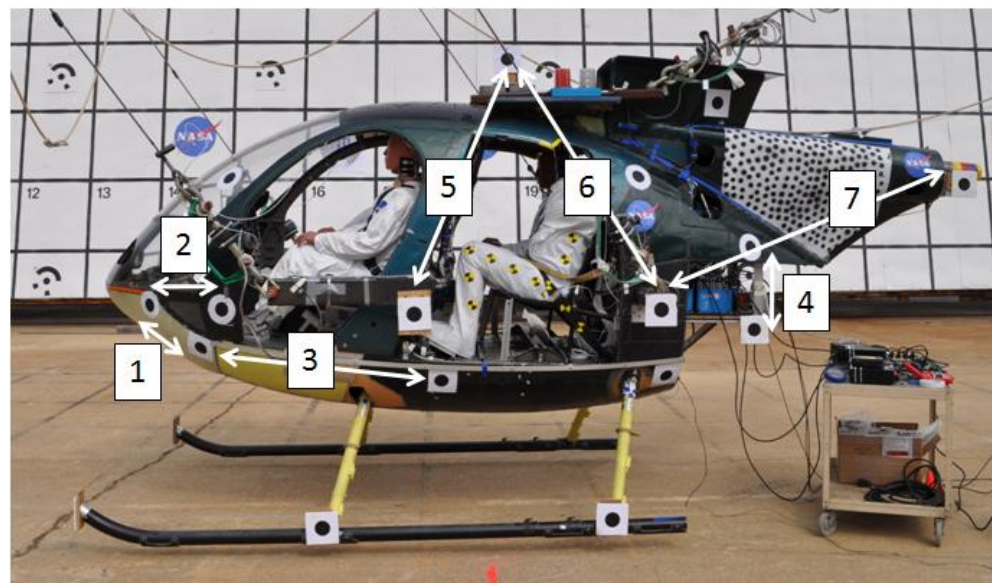
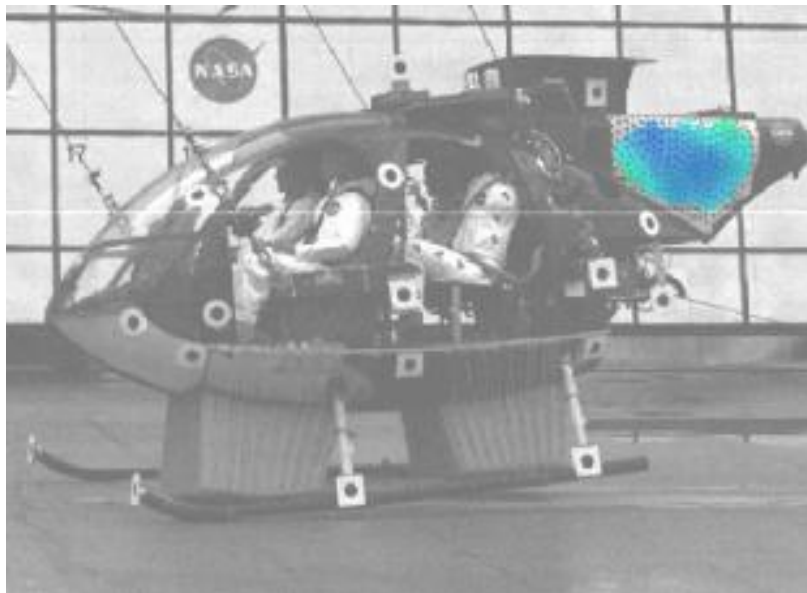




# MD-500 photogrammetry deformations

- Relative deflection between target locations shows gross vehicle deformation (differential displacement / relative deformation)
- Target locations picked either by hard-points, or high mass locations, or areas of interest
- ARAMIS strains computed, however the resolution was very low to achieve reportable results

|   | Vehicle locations                 | MD-500 without DEA Peak Deformation, % | MD-500 with DEA Peak Deformation, % |
|---|-----------------------------------|----------------------------------------|-------------------------------------|
| 1 | Nose to water line                | 0.28                                   | 0.85                                |
| 2 | Seat line                         | 0.43                                   | 0.47                                |
| 3 | Water line                        | 0.16                                   | 0.17                                |
| 4 | DAS shelf support                 | 2.78                                   | 0.98                                |
| 5 | Top Mass to front lifting fixture | 0.77                                   | 0.32                                |
| 6 | Top Mass to rear lifting fixture  | 0.69                                   | 0.34                                |
| 7 | Tail to rear lifting fixture      | 1.65                                   | 0.24                                |





# MD-500 reverse engineering a seat

- PONTOS / TRITOP was originally used to reverse engineer seat geometry since no drawings were available
- Hemispherical drop tests were conducted on the cloth were used the material property cards



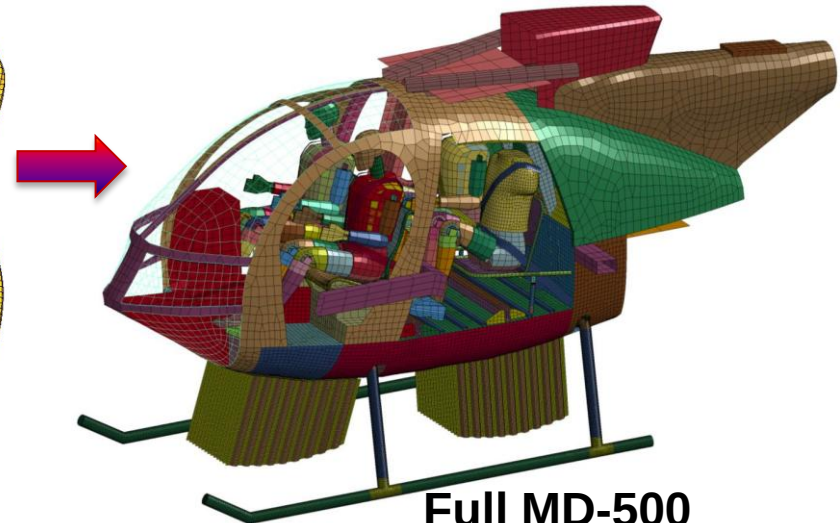
**Geometry**



**Targets**



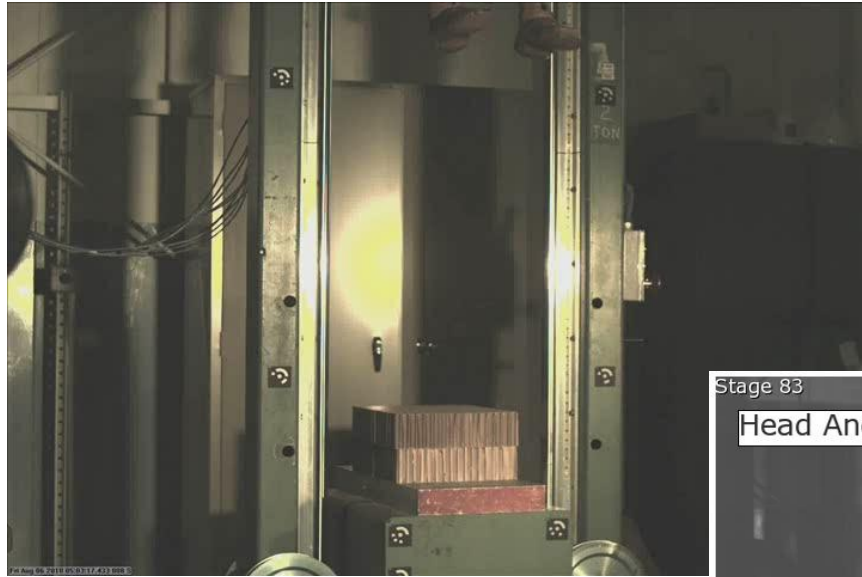
**Seat FEM**



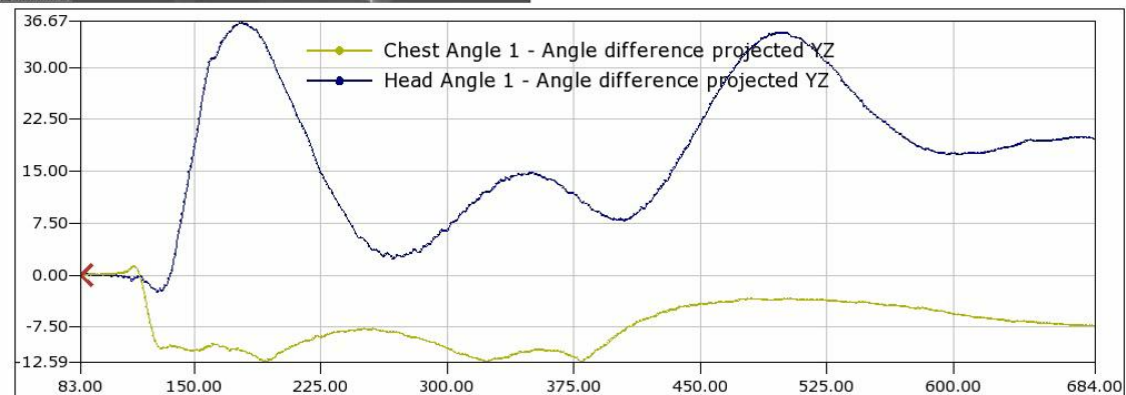
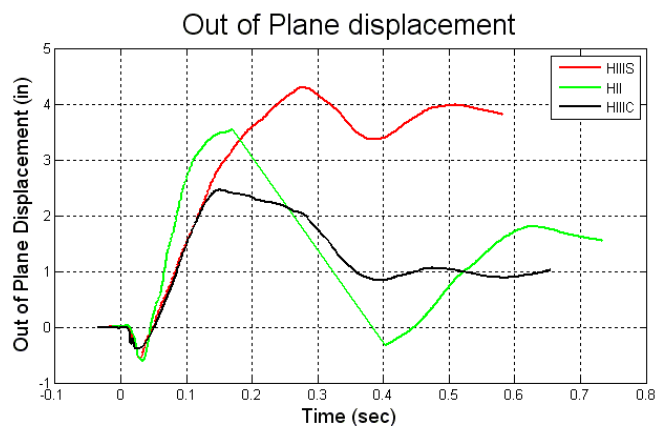
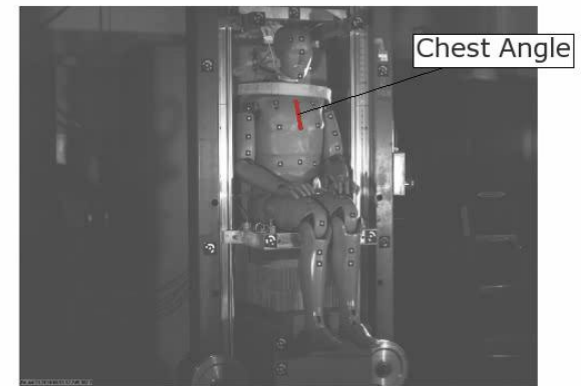
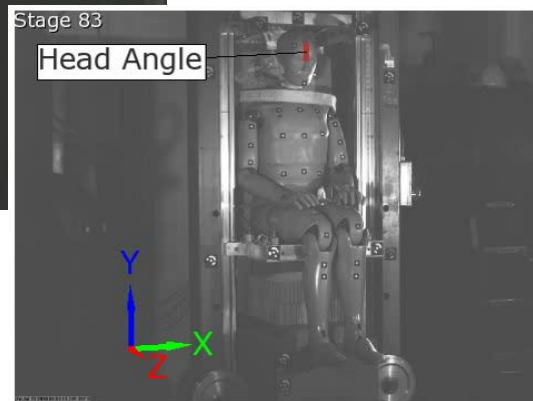
**Full MD-500  
FEM**



# ATD research – Vertical impact testing



- Purely vertical tests were conducted to study the performance of Hybrid III ATDs under vertical loading conditions



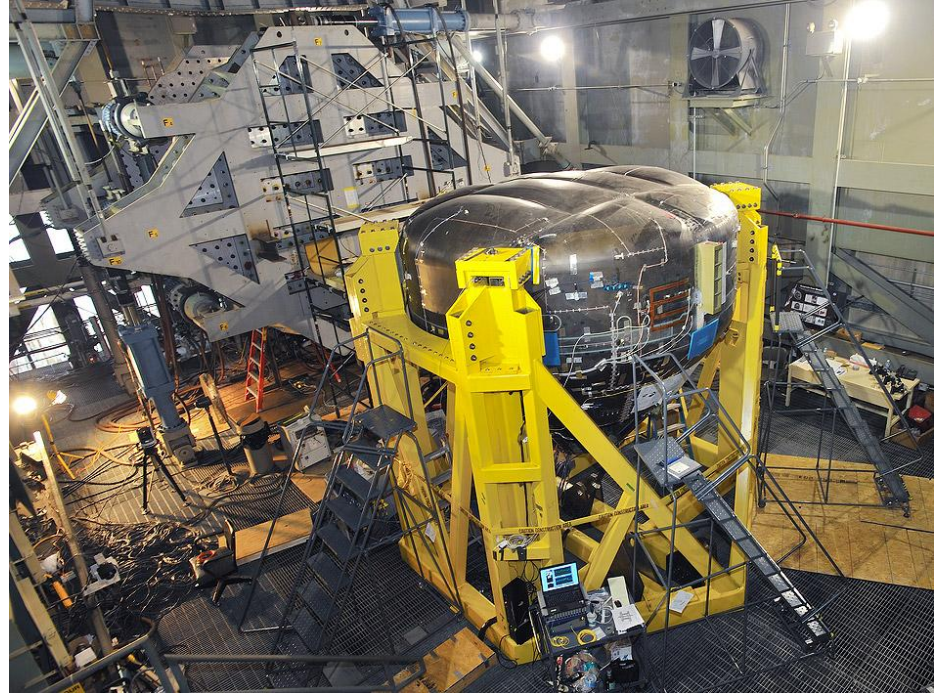


# NASA Spacecraft Photogrammetry Applications





# Composite Crew Module - CCM



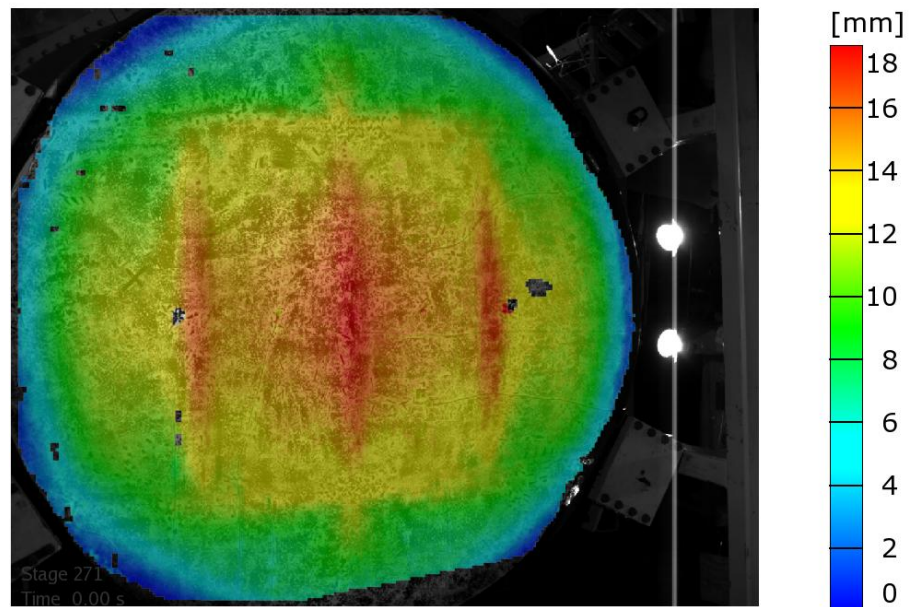
- Full Scale replicate of the Orion capsule made entirely of composite materials
- Goal: gain experience in making composite spacecraft
- Destructive pressurization test occurred at Langley 2009



# CCM – Burst Test – October 2009



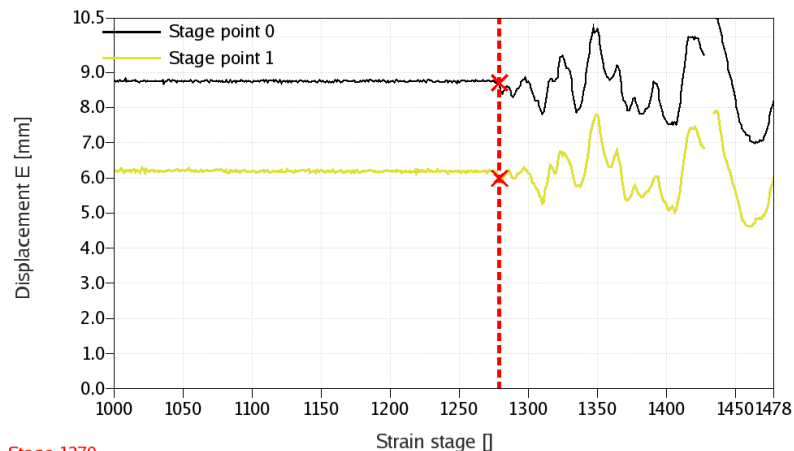
Displacement E





# CCM – burst test – determination of failure

- Failure was determined by the photogrammetric displacement measurements

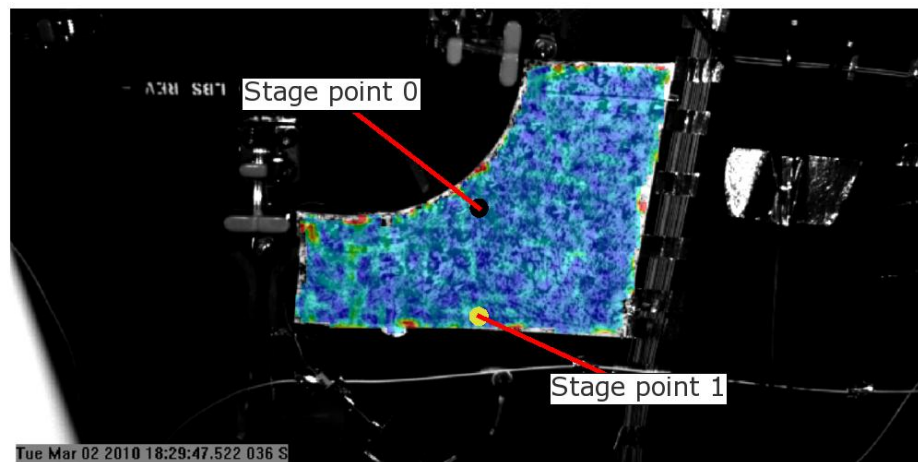
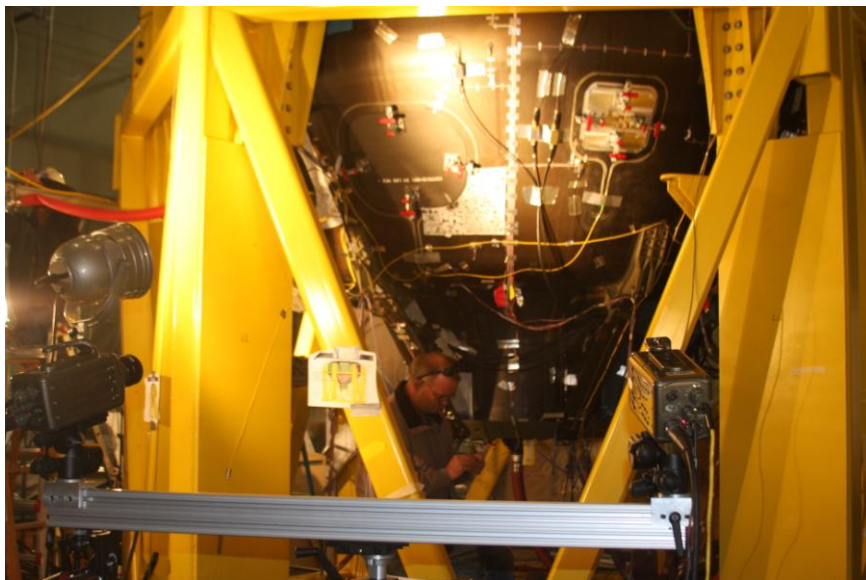


Stage 1279

ARAMIS

3/3/10

gom  
www.gom.com





# Orion half-scale testing

## Kennedy Sand Modeling Vertical Drop Test 3

Nominal Test Conditions:

Sand 5% MC, 100 PCF Dry Density

35 fps Vertical Velocity

28 Degree Pitch

Two Views

30 Pictures Per Second

NASA-Langley

July 8, 2009



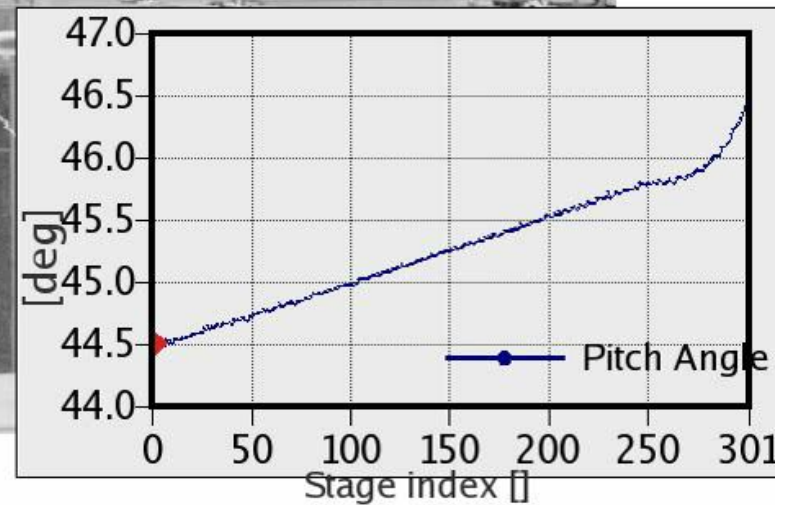
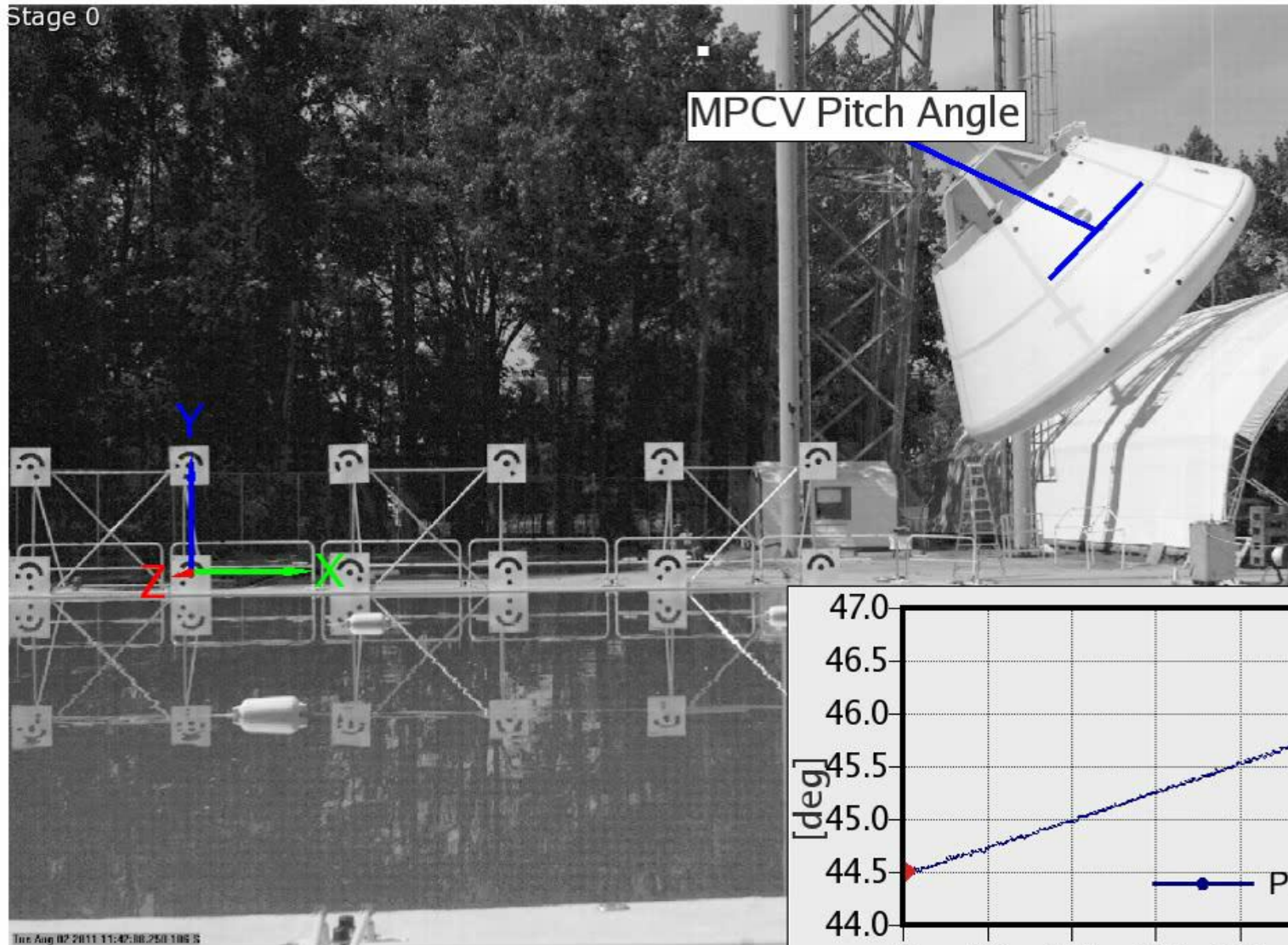
# Orion Boilerplate Test Article (BTA) - Hydro Impact Basin splash tests





# BTA HIB swing tests

Stage 0





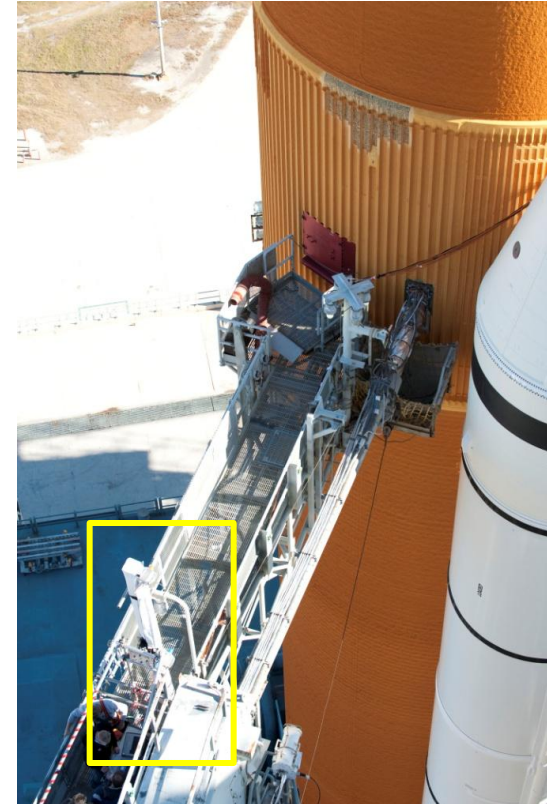
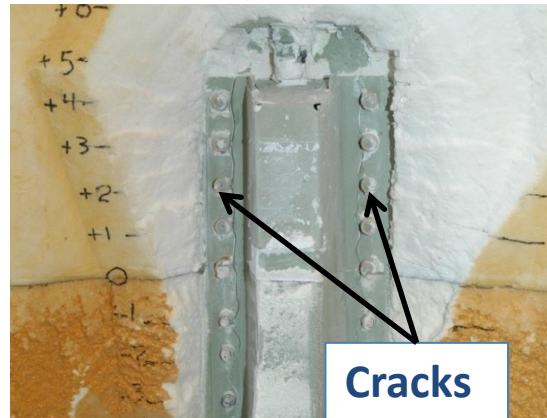
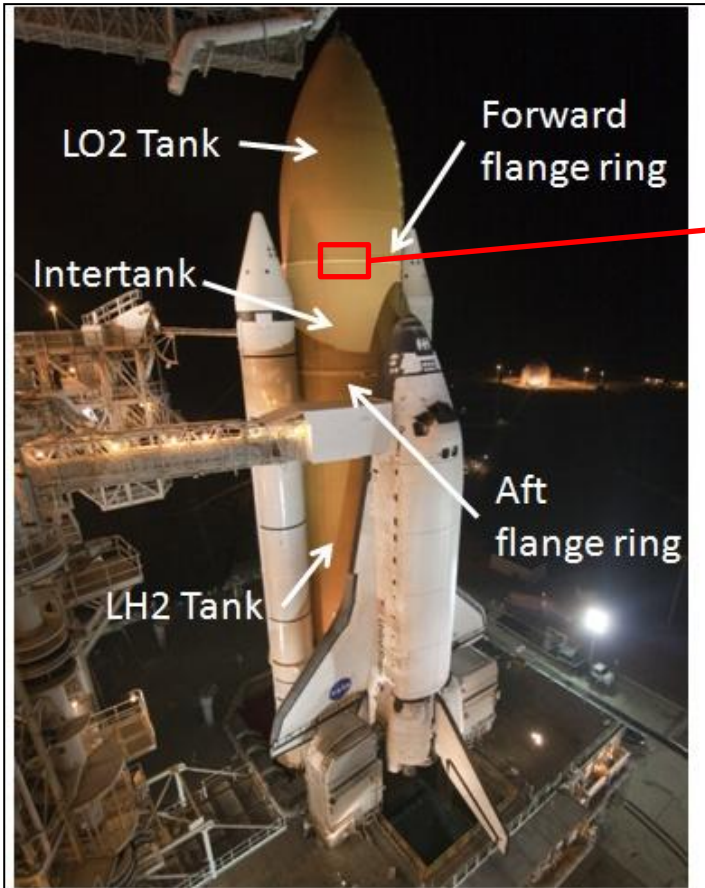
# BTA HIB drop tests

P2T4 PONTOS Project.dyn  
Date: 8/30/2012





# STS-133 ET deformation – KSC - LC-39a



- ARAMIS cameras filming ET panel 6 during ~8 hour tanking test



# STS-133 – GUCP performance assessment

ET hardware



- STS-133 scrubbed due to GUCP vent leaks
- Previously STS-119 and -127
- Installation procedure questioned

Engineering Test Stand



Outside view

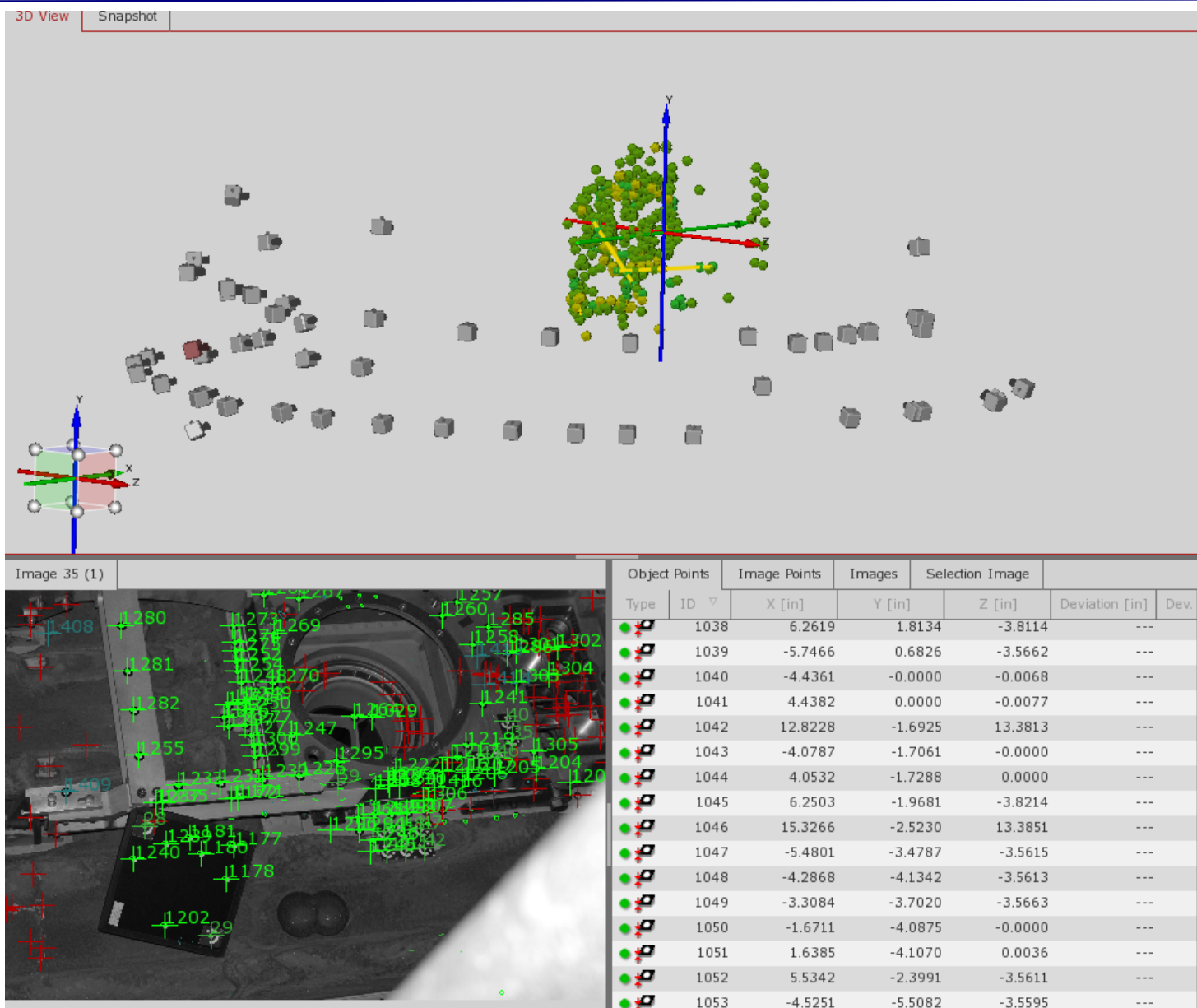


Inside view

- Two sets of static cameras were positioned to view the front and back side of the test stand
- Record the relative difference in motion between the outer mounting hardware and the inner seating hardware

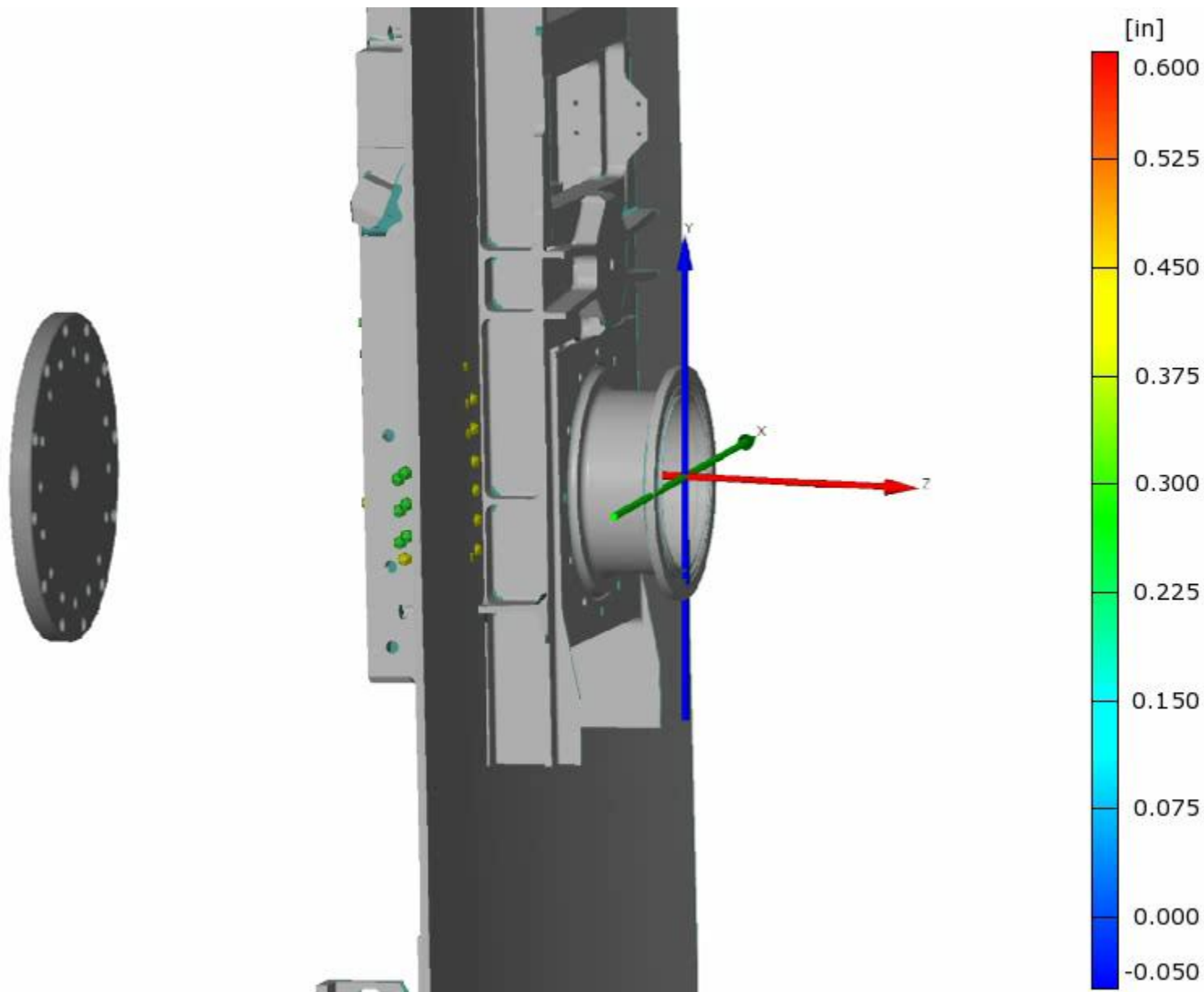


# GUCP – TRITOP - Inner and outer view stitching





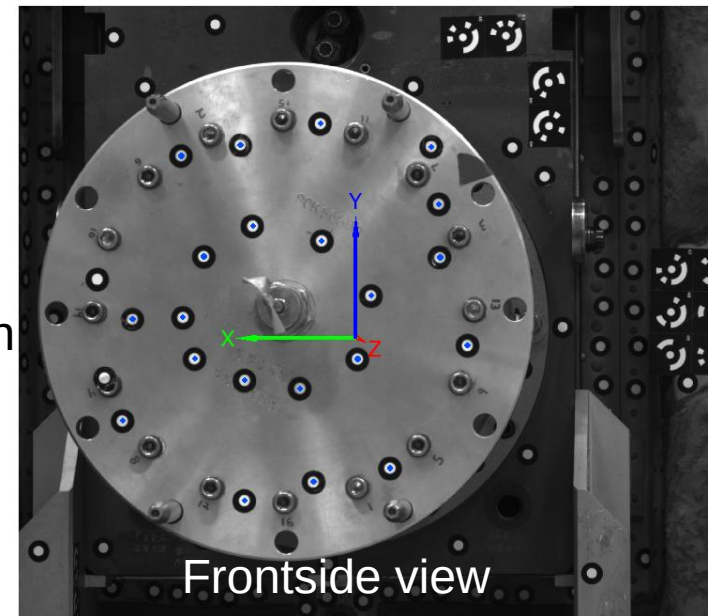
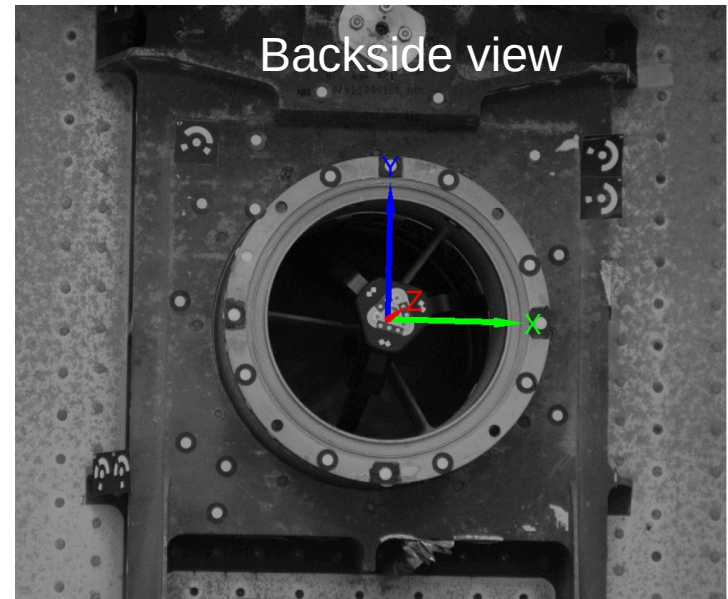
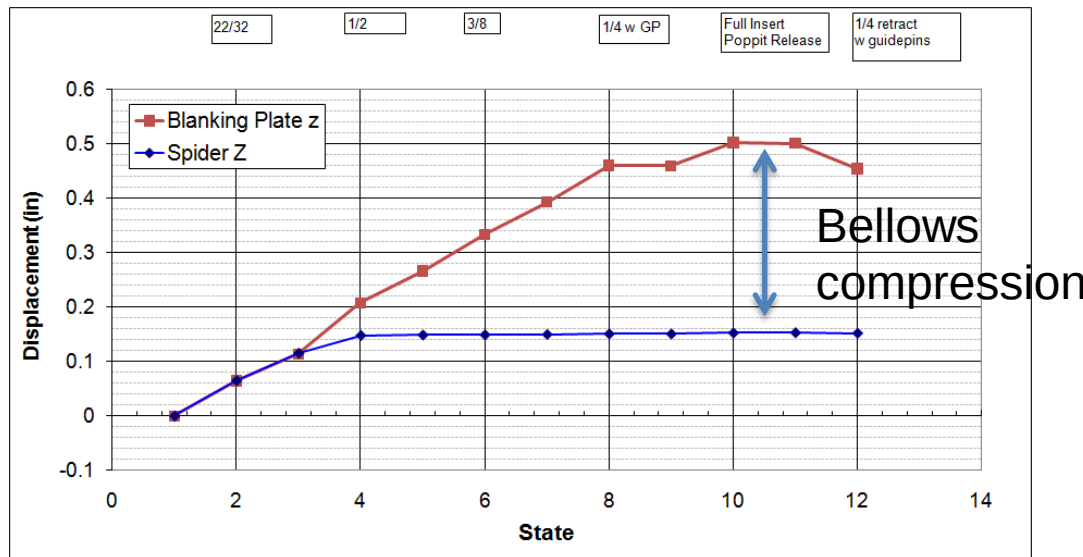
# GUCP - PONTOS motion registered with CAD





# GUCP performance assessment

- PONTOS data shows the time and location of “seating” of the GUCP seal
- It also shows the compression of the bellow by examining relative displacements between the two after seating

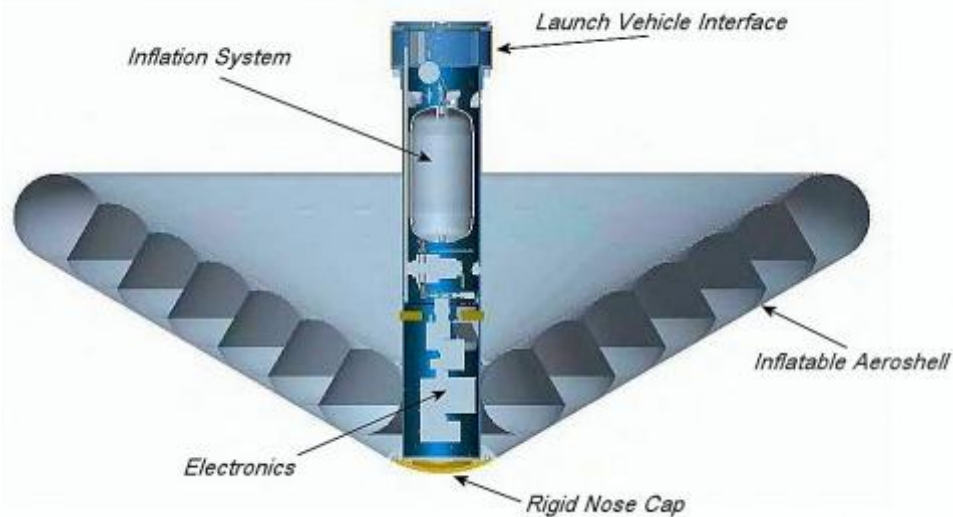




# Hypersonic Inflatable Aero Decelerators (HIAD)

- NASA is developing re-entry vehicles through the Office of Chief Technology which use an inflatable expanding heat-shield instead of the traditional rigid
- Recent example is IRVE-3 (Earth Re-entry Vehicle 3)
  - Launched July 2012 from Wallops Launch Facility (Virginia)
  - 3m HIAD used to expand the HIAD knowledge base

Generalized HIAD configuration

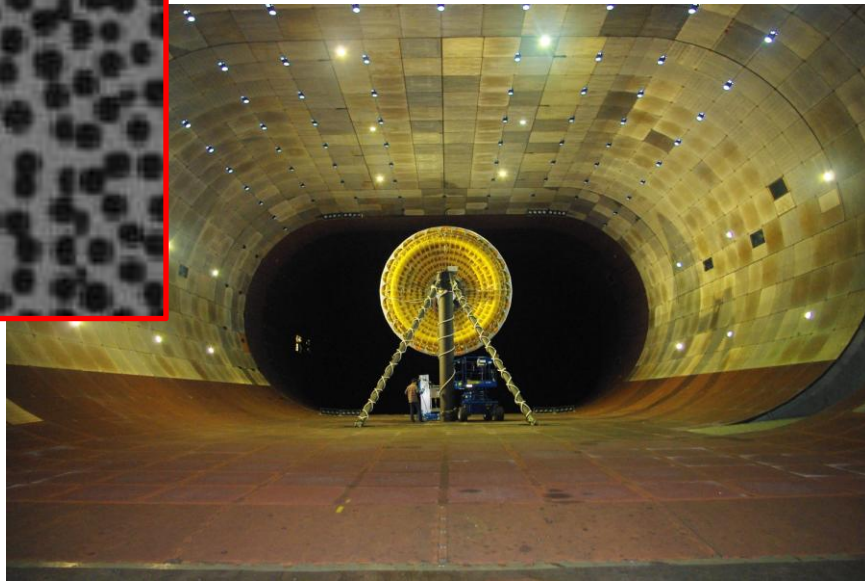
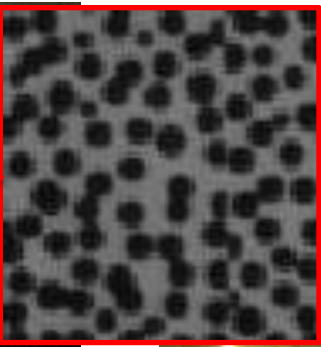
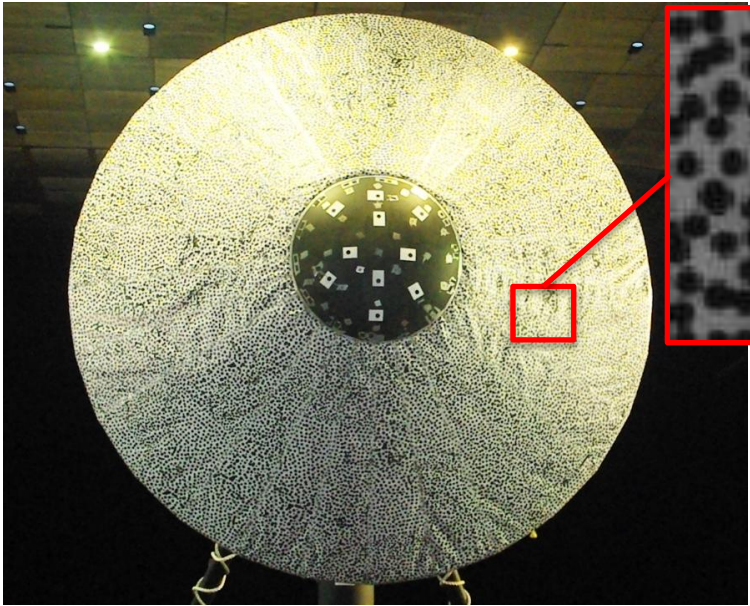
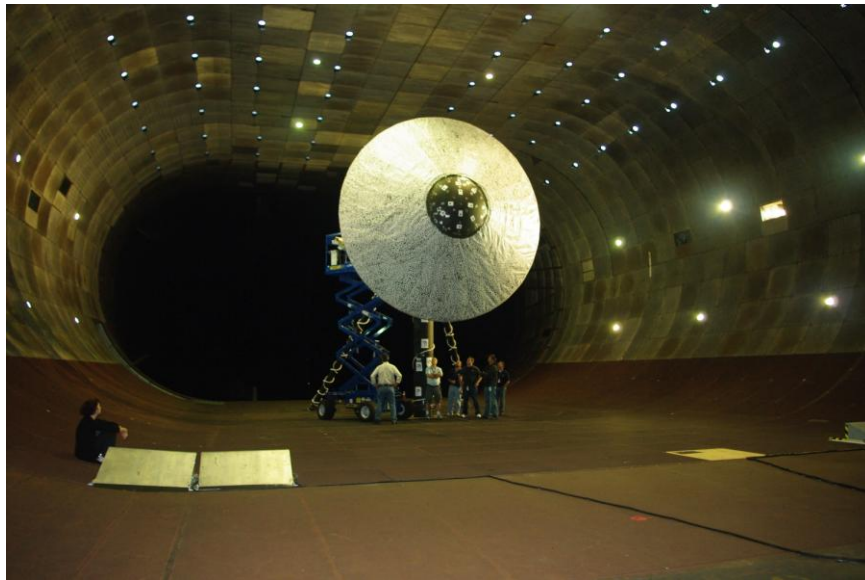


Onboard video of IRVE-3 deployment





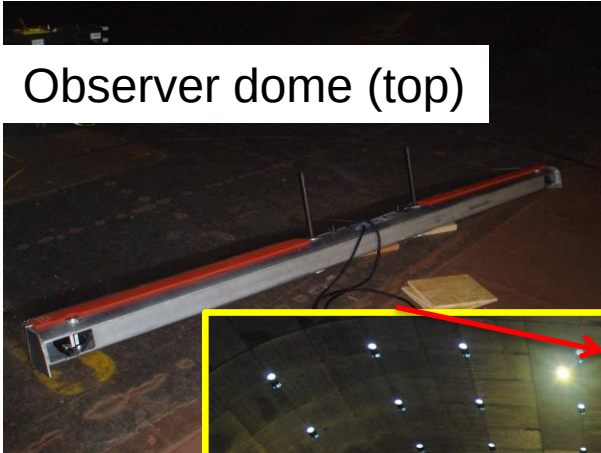
# 6m HIAD – NASA Ames Research Center NFAC



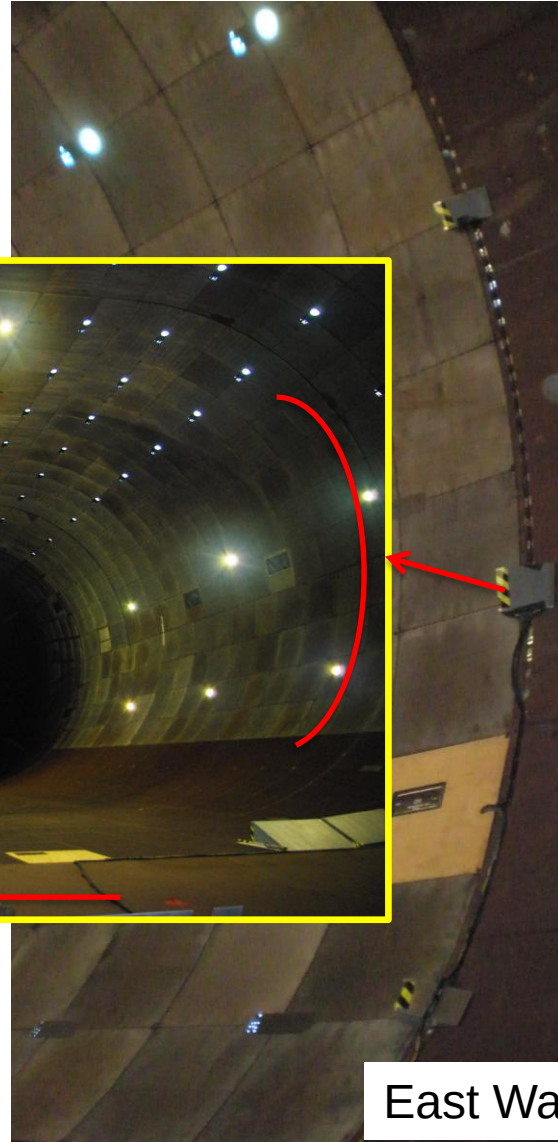


# HIAD – Camera setup

Observer dome (top)



Mic Stand (floor)

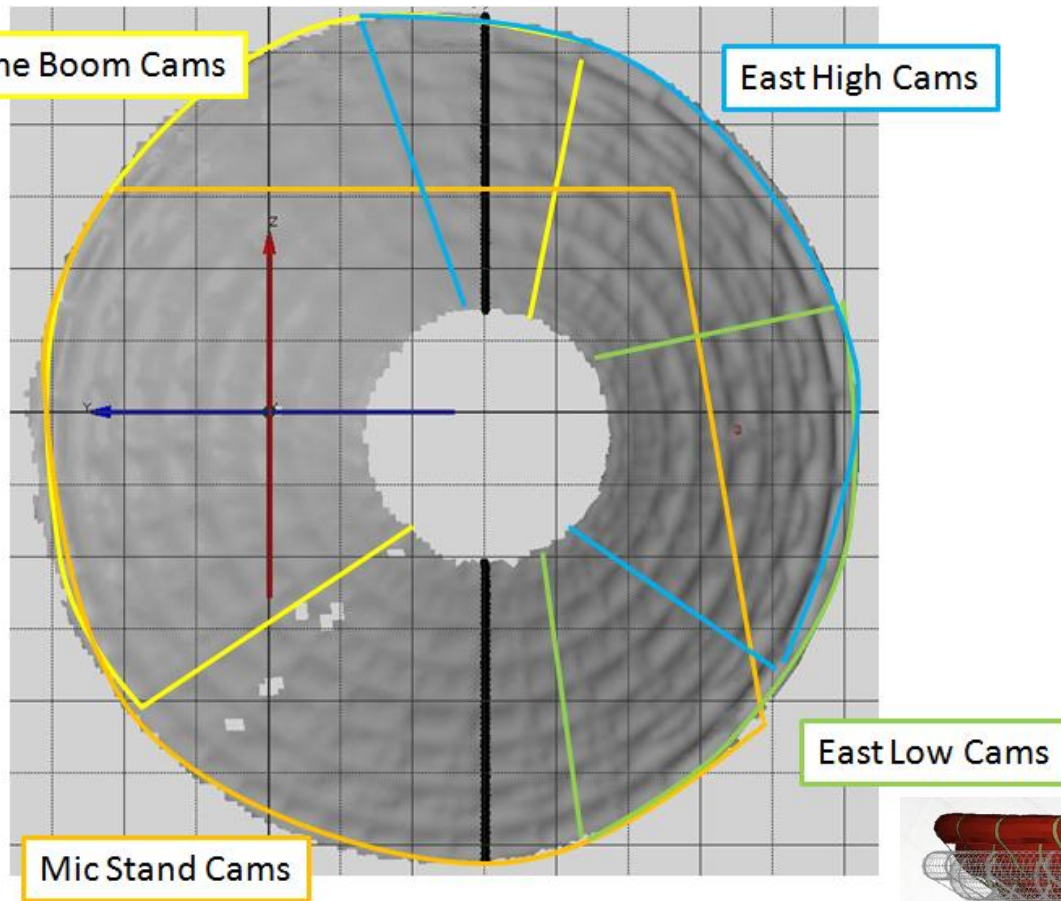


East Wall cameras – 2 pair



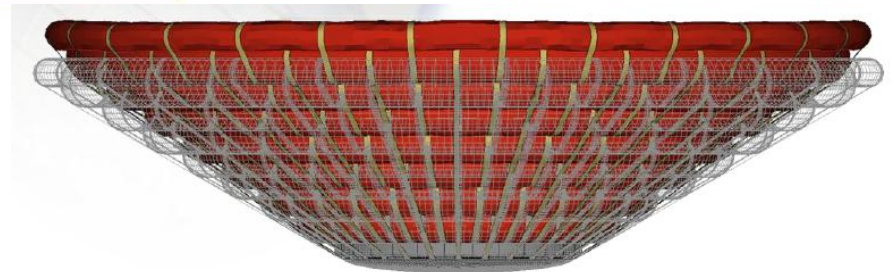
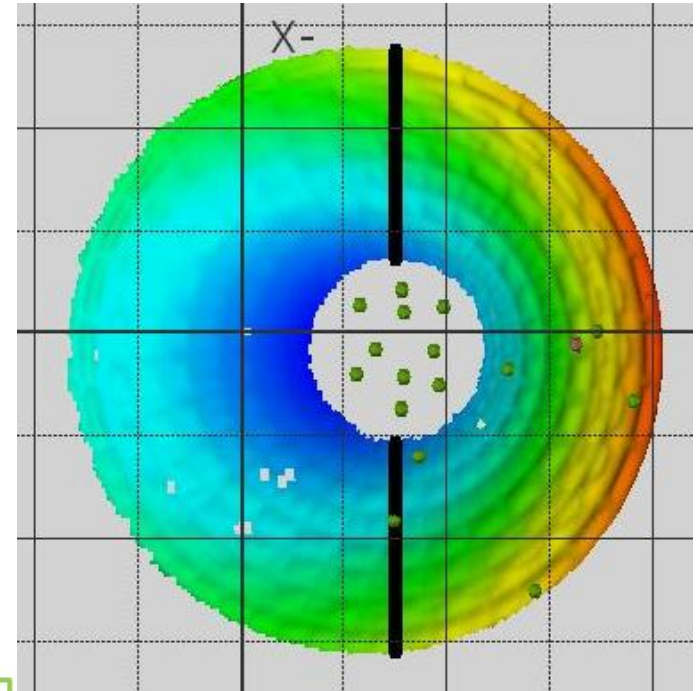


# HIAD results



Surface Profile

Z on XYZ deformation



Deformed (red) vs. Undeformed (clear)

