Digital Image Correlation with Color Filtering for Strain Isolation Webinar

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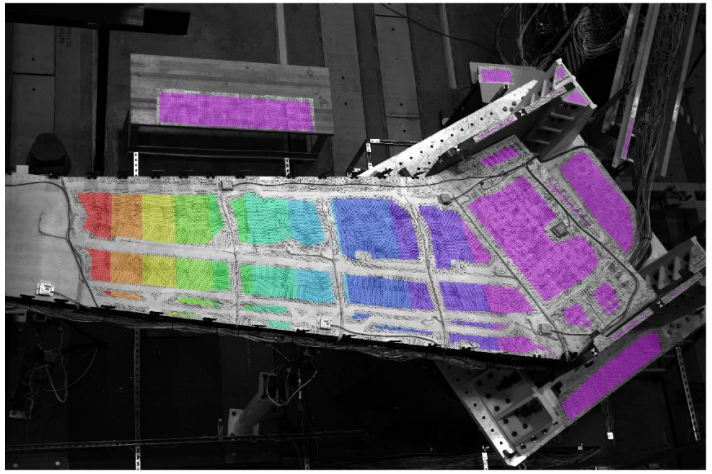
Overview

- Introduction
- Background
- Test & Validation
- Applications

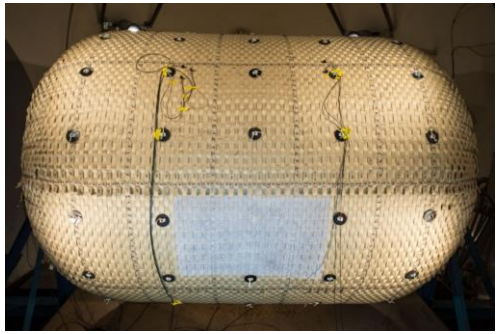
Introduction

- Digital Image Correlation (DIC), also known as photogrammetry, is a non-contact, optical technique for measuring full-field deformation, displacement, and strain on the surface of a structure during mechanical testing.
- DIC estimates full-field coordinates and displacements through a series of sequential images taken of a patterned surface.
- DIC assumes the pattern applied to a surface follows the deformation of the underlying test article.



Passive Aeroelastic Wing[1] (AFRC)

Shell Buckling[2] (MSFC)



Inflatable Habitats[3] (JSC)

[1] Dawicke, D. S., “Digital Image Correlation Applications at NASA Langley Research Center (1990 to 2025),” ASTM Workshop on Novel and Emerging Uses of Sensor Technology in Mechanical, Fatigue, and Fracture Testing, May 2025.

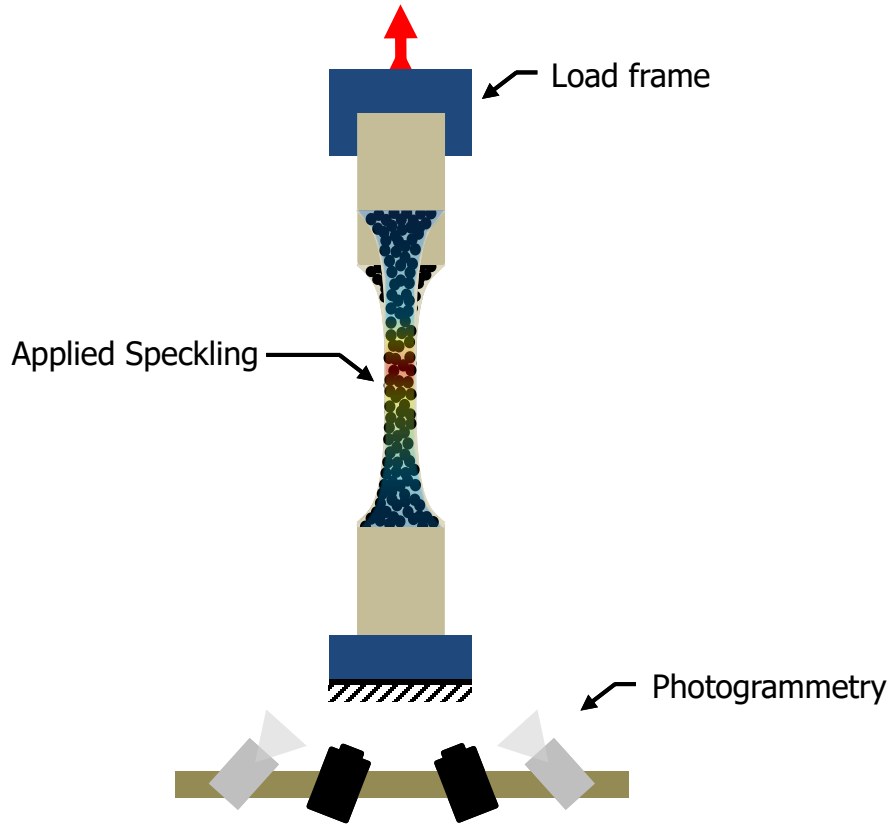
[2] Hilburger, M. W., et al. “Subscale and Full-Scale Testing of Buckling-Critical Launch Vehicle Shell Structures,” 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, April 2012. https://doi.org/10.2514/6.2012-1688

[3] Valle, G., Litteken, D., Jones, T. C., “Review of Habitable Softgoods Inflatable Design, Analysis, Testing, and Potential Space Applications,” AIAA Scitech 2019 Forum, January 2019. https://doi.org/10.2514/6.2019-1018

Introduction

Digital Image Correlation Process:

1. Define Test Parameters
   - Test Article Design
   - Areas of Interest (AOI)
   - Boundary Conditions
   - Test Operations Plan
2. Surface Preparation
   - Speckling, Markers
3. DIC Configuration
   - Cameras, Lens, Stand-Off Distance, Lighting
4. Perform Test
5. Analyze Results



DIC Example

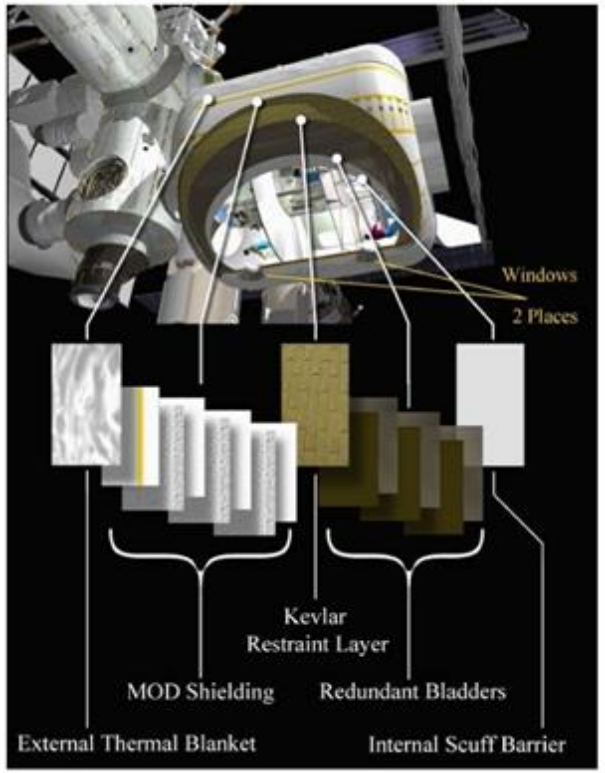
Background

Inflatable Structures

- Fabric-based pressure vessel composed of a layered soft-goods assembly.
- Structural testing focuses on the restraint layer.

Recent Events

- Bigelow Expandable Activity Module (BEAM) deployed on the International Space Station (ISS) in 2016, which increased the technology readiness level of human-rated inflatables.
- NASA is currently working with commercial companies to develop and test large scale inflatables to be used as crewed habitats for low-Earth orbit, deep space, and surface missions.



Multi-Layered Inflatable Structure[4]

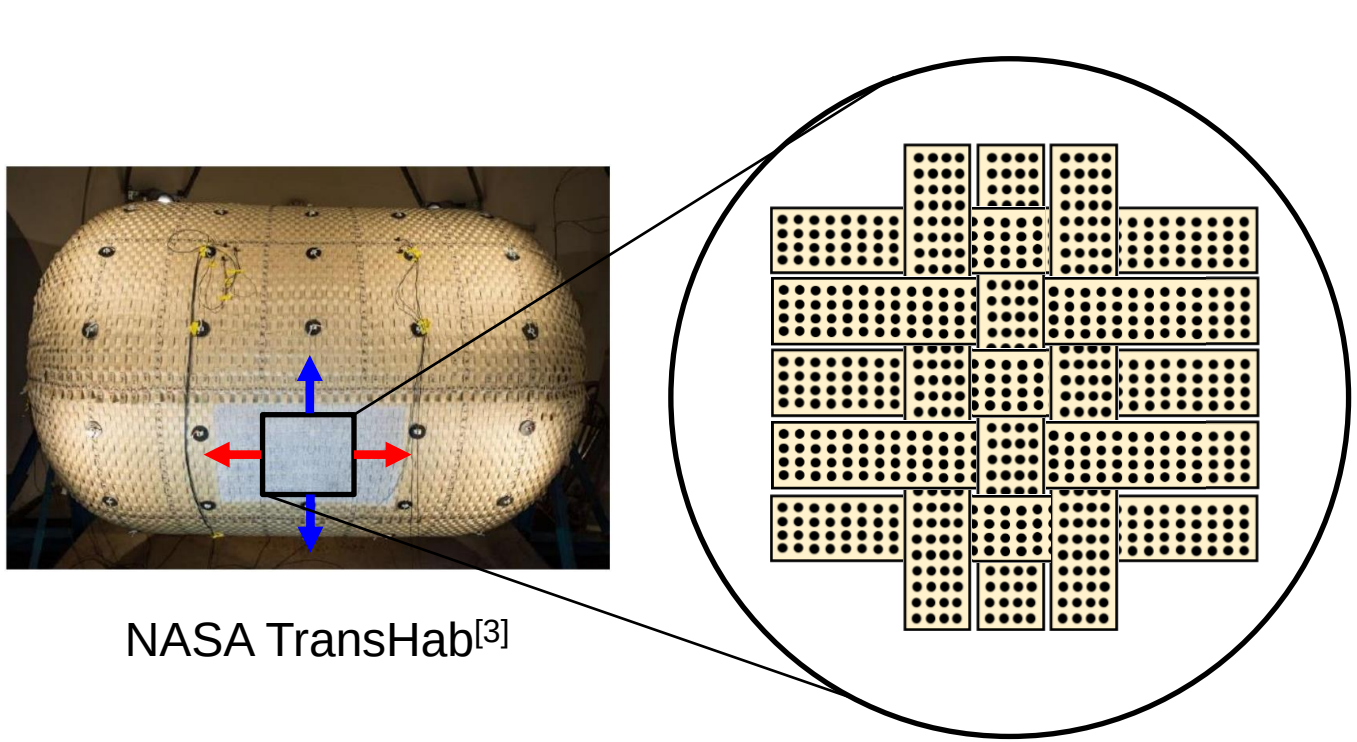
Bigelow Expandable Activity Module on the ISS[5]

[4] NASA JSC S99-05362
[5] NASA JSC ISS067E214089

Background

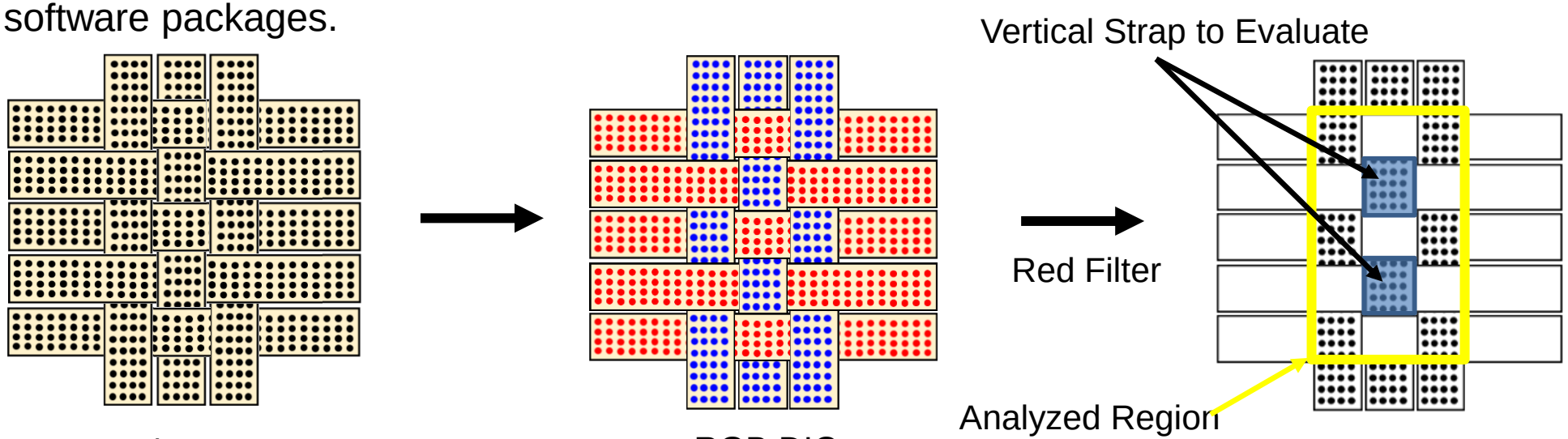
Applied Problem Case: Crewed Inflatable Space Habitats

Primary Goals: Reduce DIC Analysis Time & Improve Result Accuracy



Background

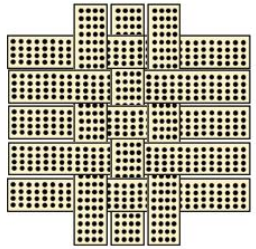
- NASA's inflatable space structures are constructed using bi-directional straps arranged in a basket-weave pattern, shown below.
- When evaluating inflatable space structures during testing, monochrome digital image correlation (DIC) is typically utilized to measure strap elongation. This method is effective at determining average strain along a single strap but has reduced accuracy due to the influence of orthogonal straps.
- A novel approach using color filtering was evaluated where a post-processing filter can be applied to remove speckles on orthogonal straps, reducing the influence of these dots on the areas of interest and resulting in higher fidelity data.
- This process is done by applying red dots horizontally and blue dots vertically and, after applying the filter, an engineer can isolate a single direction of material to be evaluated using typical digital image correlation analysis software packages.



Background

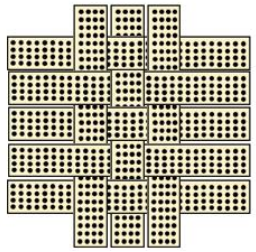
Previous Monochrome Method

Prepare Sample using **Black-White** Speckle



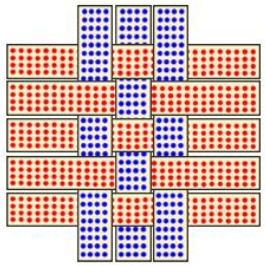
Perform Test & Capture **Monochrome** Images

Process Monochrome Images in DIC Software



New Color Method

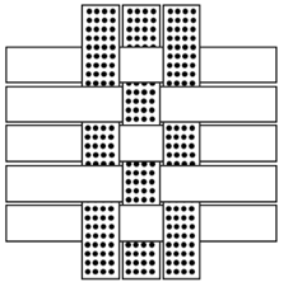
Prepare Sample using **Red-White & Blue-White** Speckle



Perform Test & Capture **Color** Images

Convert Color images to Monochrome using RGB Filtering

Process Monochrome Images in DIC Software



Demonstration Test Methodology

Demonstration test was conducted on a sub-component specimen:

Testing Procedures:

Specimen: 1.75” Kevlar, 8000 lbs ULT.

Preconditioning: 3 x 4000 lbs with 5 second dwell

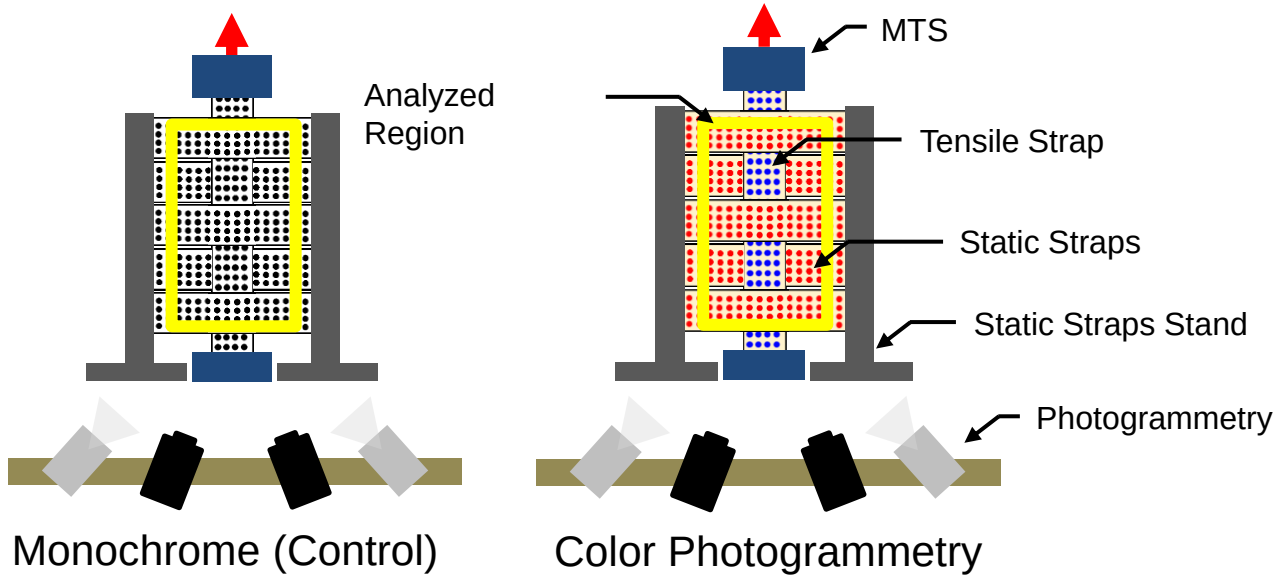
Test Run: 4000 lbs at 1 inch/minute displacement

Photogrammetry:

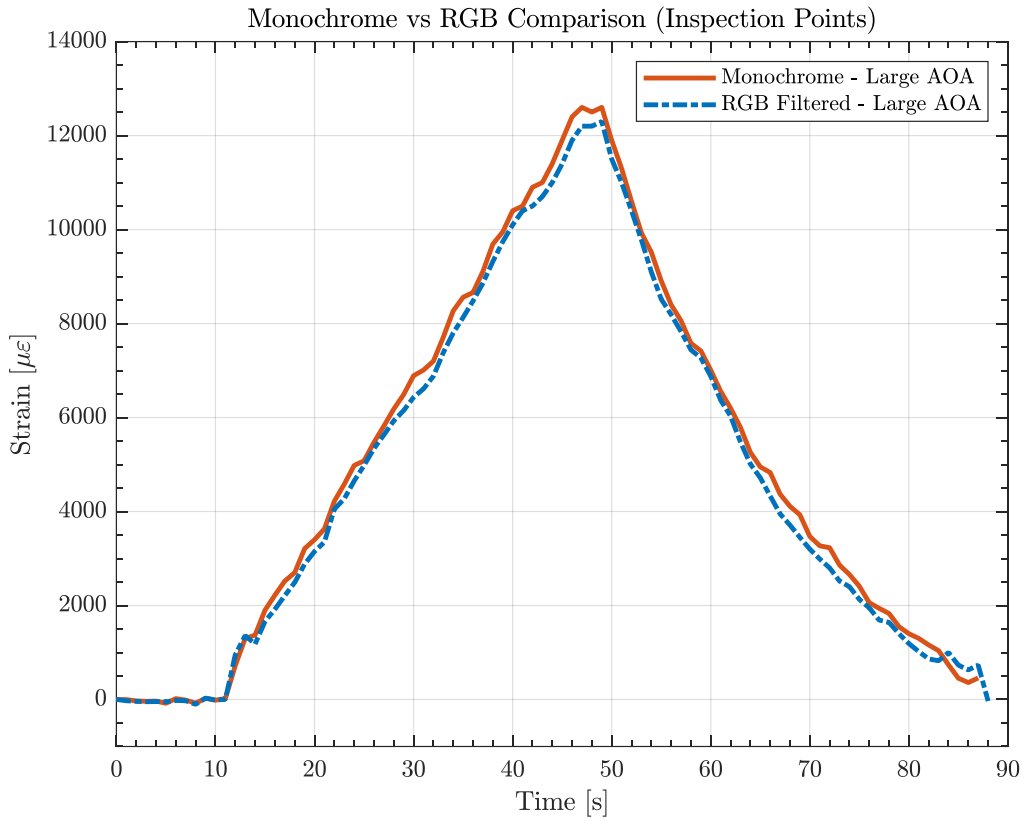
- 2 x 5MP Color Stereo Cameras
- Created a custom DIC Capture Software to capture RGB8 images at 1Hz

RGB Post Processing:

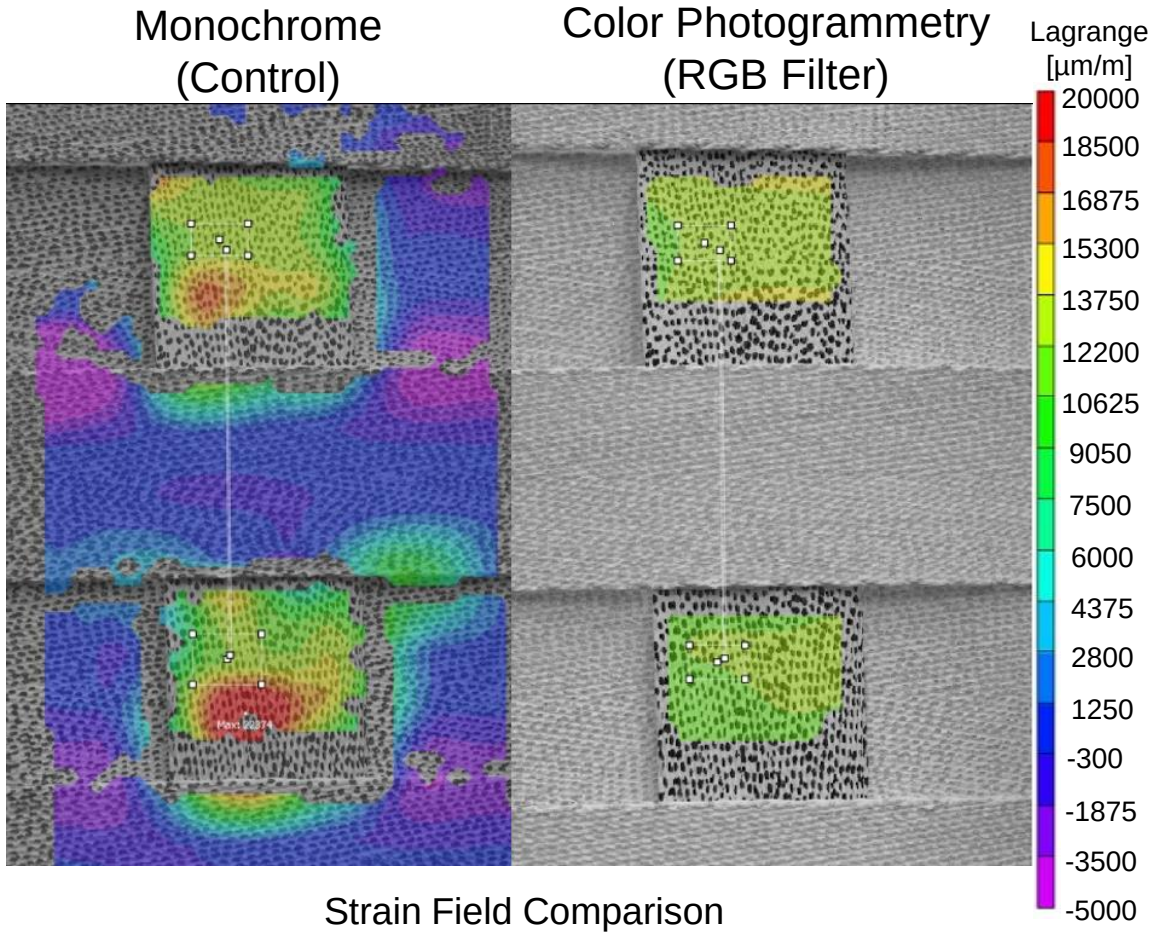
- A Python Script processed images to only enable the Red RGBA Channel and rename for analysis.



Demonstration Test Results



Strain Comparison between Control and RGB Filtered DIC using Inspection Points

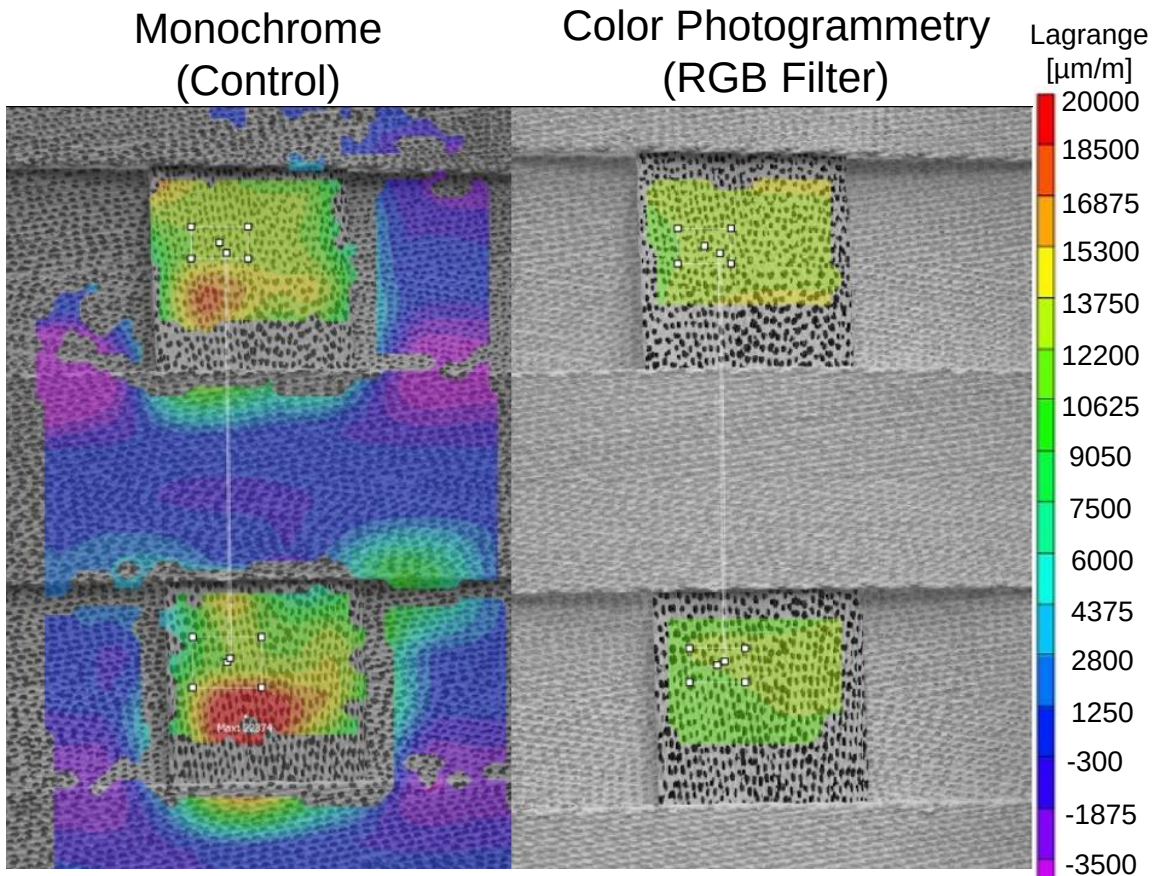


Strain Field Comparison (Strain at 4000 lbs)

Demonstration Test Results

Key Takeaways:

- **Monochrome Control**
  - Significant error/false hotspots caused by overlapping straps
  - Strain can be extracted by a trained engineer, but is time consuming
- **Color-Filtered**
  - Reduced error due to overlapping straps
  - Easier to identify strain along strap sections

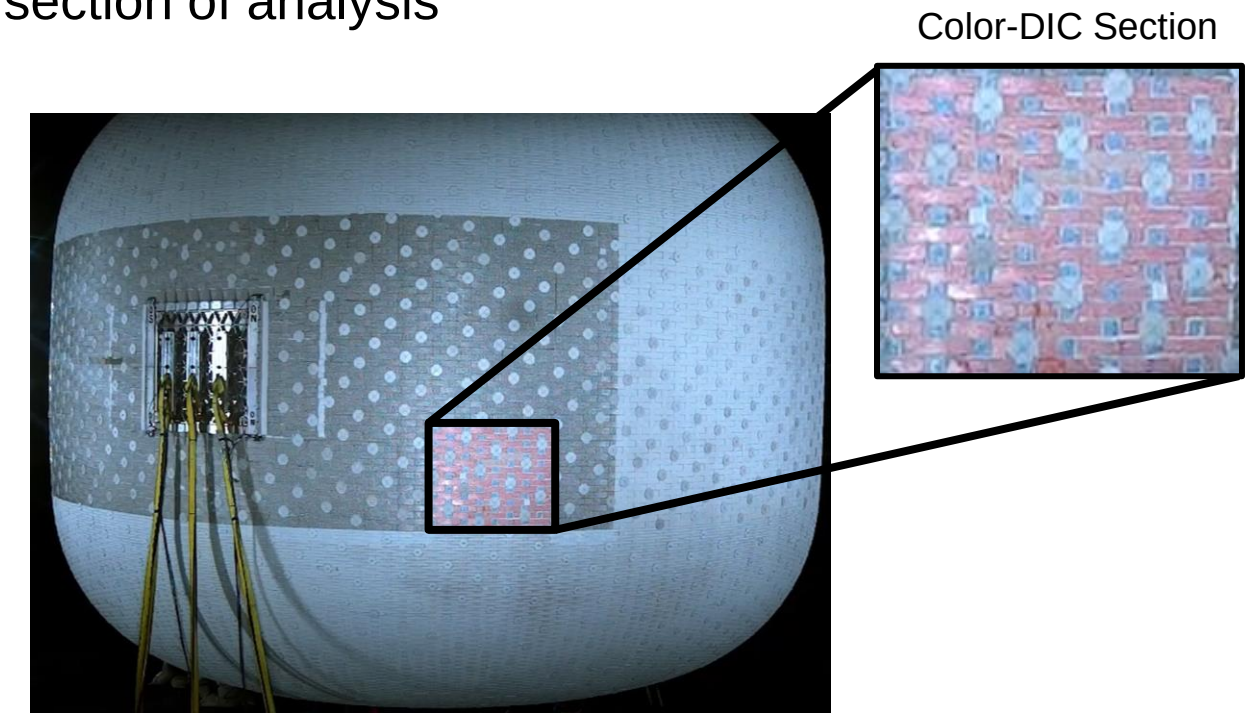


Strain Field Comparison
(Strain at 4000 lbs)

Additional Testing

Further Validation:

- **Color-DIC was applied during a full-scale inflatable burst test**
  - Validation on a Curved test article
  - Demonstrated on a larger section of analysis



Sierra Space's LIFE Habitat
Full-Scale Burst Test[6]

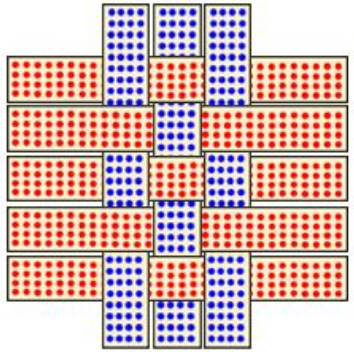
[6] "NASA Conducts 2nd Full-Scale Inflatable Habitat Burst Pressure Test," Retrieved from https://www.youtube.com/watch?v=K1hU14RlhRs

Applications

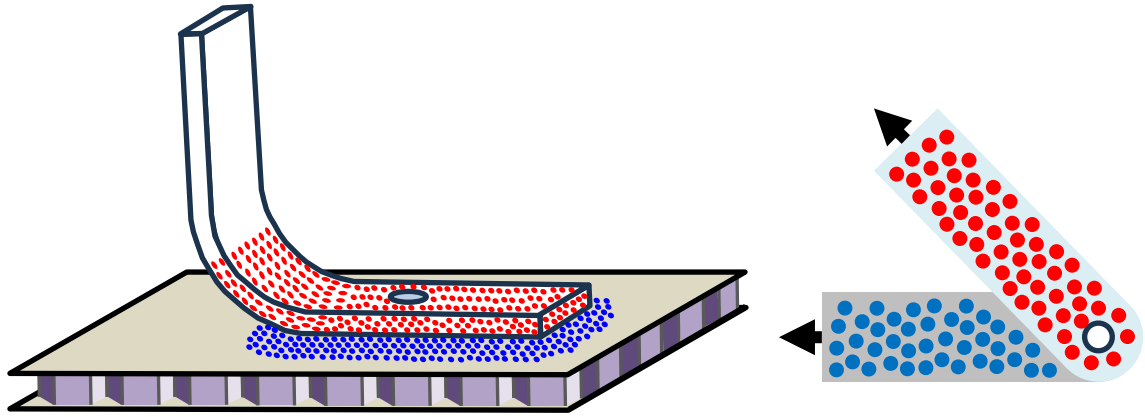
- **The Color-DIC Method is effective for evaluating strain on structures that have overlapping features**

Potential Applications:

- Crewed Inflatable Space Habitats
- Overlapping Joints & Fixtures
- Rocket Engine Gimbal Structure
- Parachutes
- Sailboat Sail Sections
- Etc.



Crewed Inflatable Habitats



Overlapping Joints

Acknowledgements

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Questions?

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