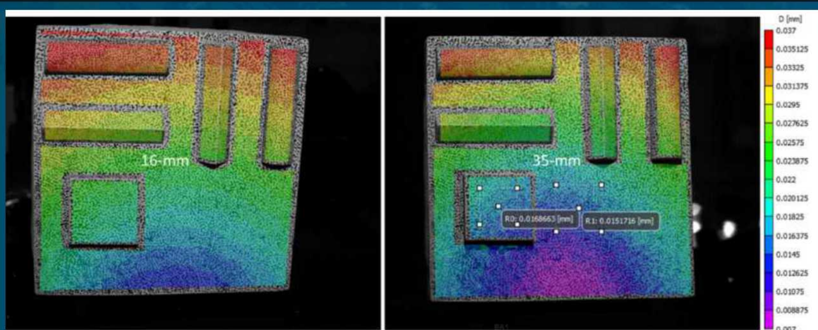
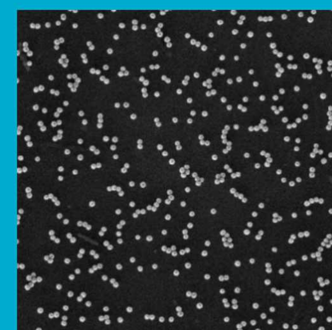
https://sem.org/

SAND2018-5917C

Digital Image Correlation DIC – Challenge Meeting





PRESENTED BY

Phillip Reu

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DIC Challenge Charter

The DIC Challenge seeks to:

- Provide sample images for code verification and development.
- Benchmarked results for the sample images – published and peer-reviewed.
- A forum for the discussion and improvement of DIC.
- Provide image sets for all DIC modalities: Stereo-DIC (3D), Digital Volume Correlation (DVC), Scanning electron microscope (SEM-DIC)

The official charter is available at the website:
https://sem.org/dic-challenge

Current Board Members

Phillip Reu – Chairman (US – FFT Shifting)

Mark Iadicola (NIST) – co-chair

Will LePage (Univ. Mich.) – SEM challenge Lead

Helena Jin (Sandia) – DVC challenge Lead

Benoît Blaysat (University Clermont Auvergne, France) – 2D Challenge 2.0

Elizabeth Jones (Sandia) – Results analysis

Evelyne Toussaint (University Clermont Auvergne, France) – Results analysis

Hugh Bruck (University of Maryland) – Advisor at large

In memoriam – Laurent Robert

Looking for volunteers

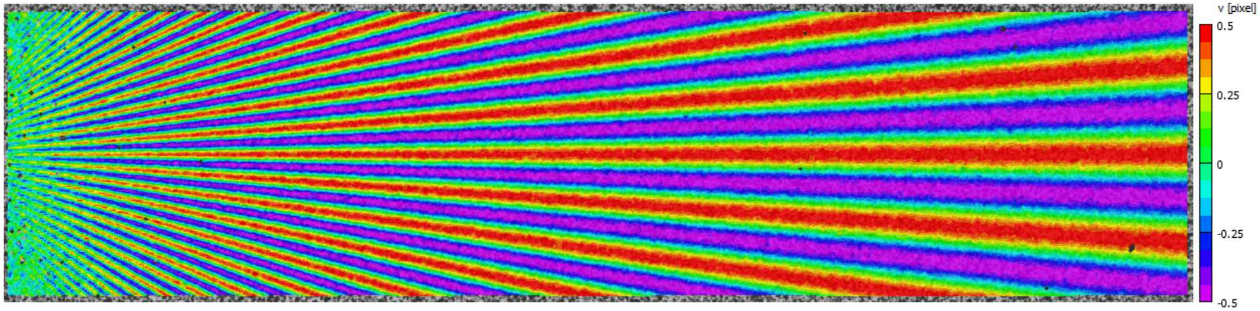
The DIC challenge is important because it is an independent organization

- No ties to any commercial or university codes
- Open and free to participate
- Code developers will run their own code ensuring "optimum" parameter selection
- Validated image sets will be available tested by many groups for testing software
- Benchmark results will be presented for all participants

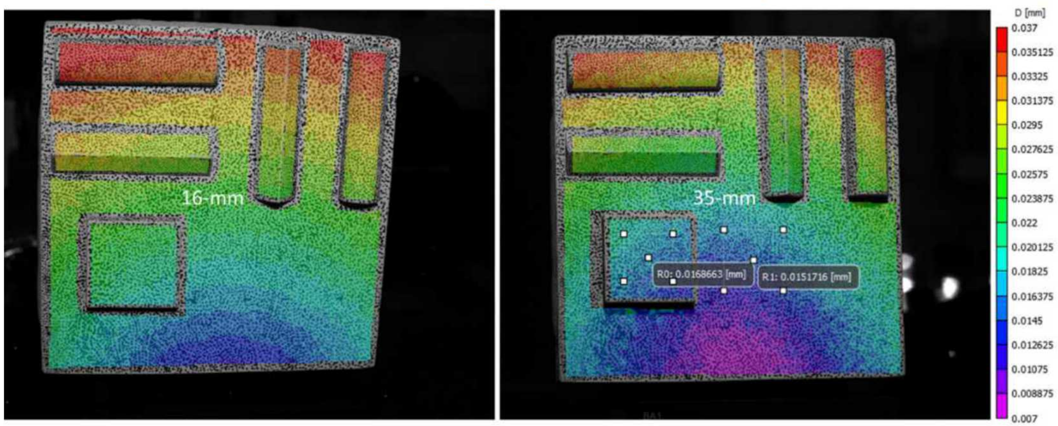
We have moved to Google Drive for better global access (sorry China).

Current state of the challenge

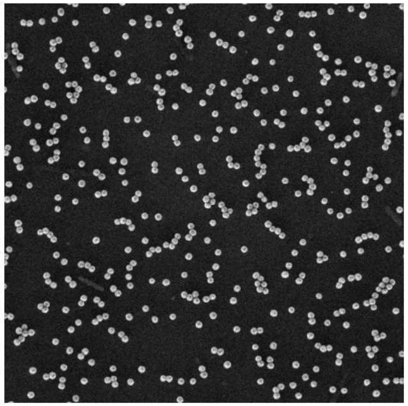
2D Challenge 2.0



Stereo-DIC Image Set Description



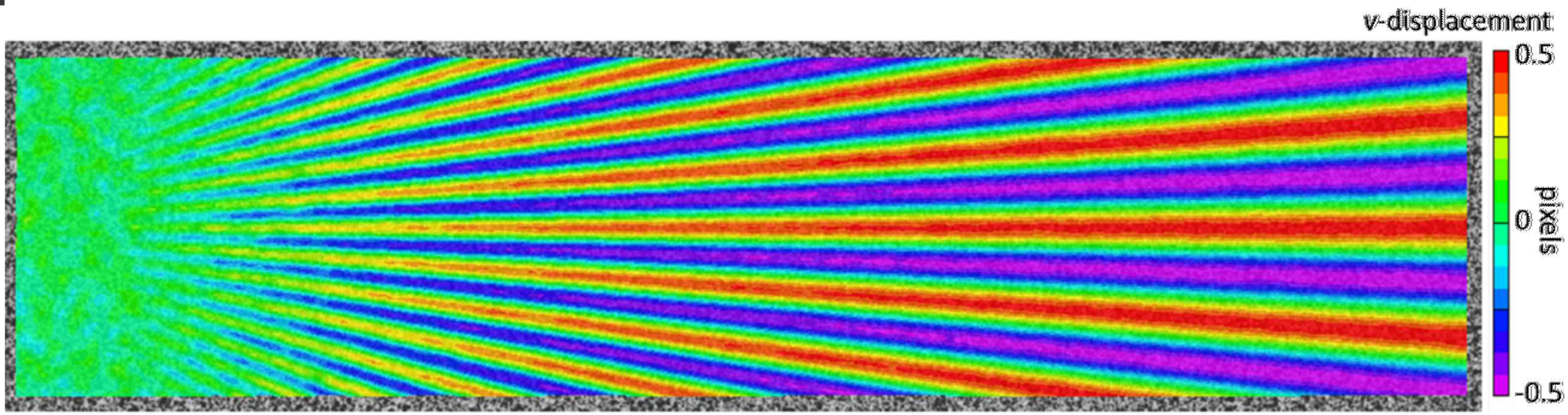
SEM-DIC Challenge



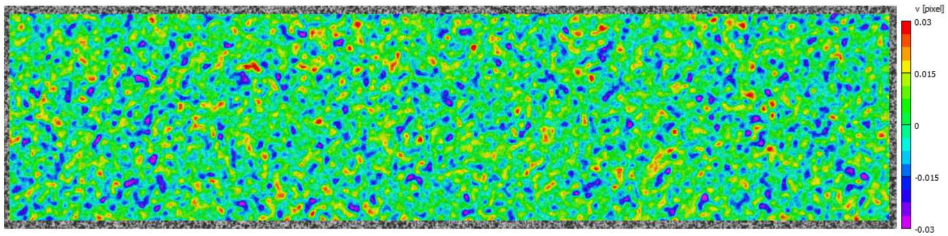
DVC-DIC Challenge

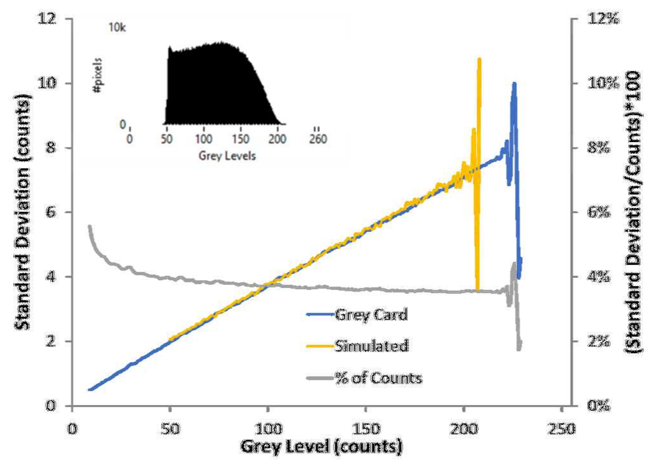
We have moved to Google Drive for better global access (sorry China).

2D Challenge 2.0 – New images for better spatial resolution studies



- Constant amplitude (±0.5 pixels) with varying period (10 to 150 pixels)
- Noise profile of Flir 5 Megapixel camera (heteroscedastic)
- Undeformed noise image for calculating noise floor.
- Line cut through the middle quickly visualizes the data.
- MATLAB script to take line cut data and calculate a spatial resolution



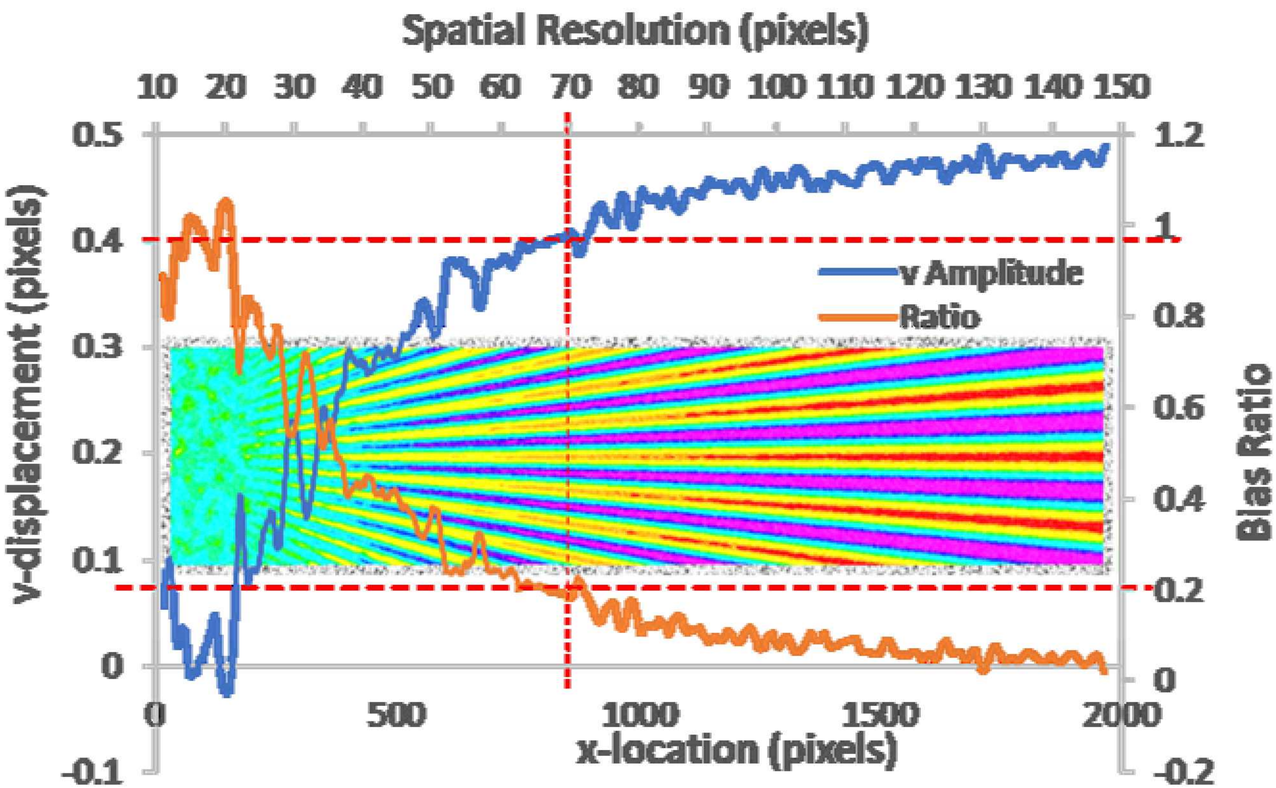


Based on References

1. Sur, F., B. Blaysat, and M. Grédiac, *Rendering Deformed Speckle Images with a Boolean Model.* Journal of Mathematical Imaging and Vision, 2017.
2. Grediac, M., B. Blaysat, and F. Sur, *A Critical Comparison of Some Metrological Parameters Characterizing Local Digital Image Correlation and Grid Method.* Experimental Mechanics, 2017. **57**(6): p. 871-903.

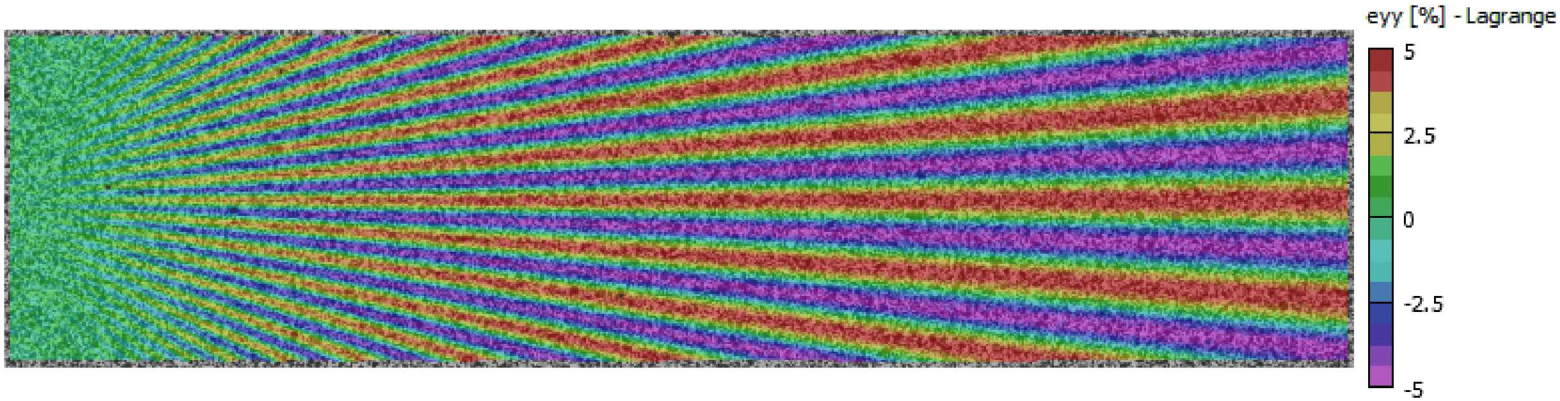
Images at:
https://drive.google.com/drive/folders/1ELWo0GMxxRBjG9KSQ8PIyMk1CL__GtLB?usp=sharing

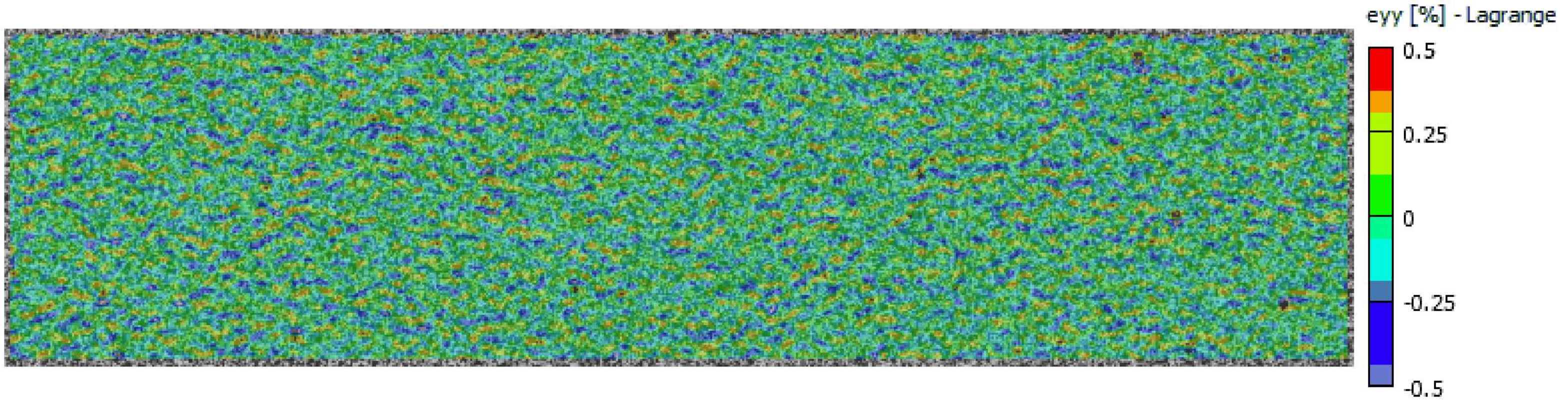
One line-cut tells the entire story. A cutoff ratio needs to be chosen.



- 90% for displacement, i.e. 10% signal loss.
- 80% for strain, i.e. 20% signal loss
- These are open for discussion!

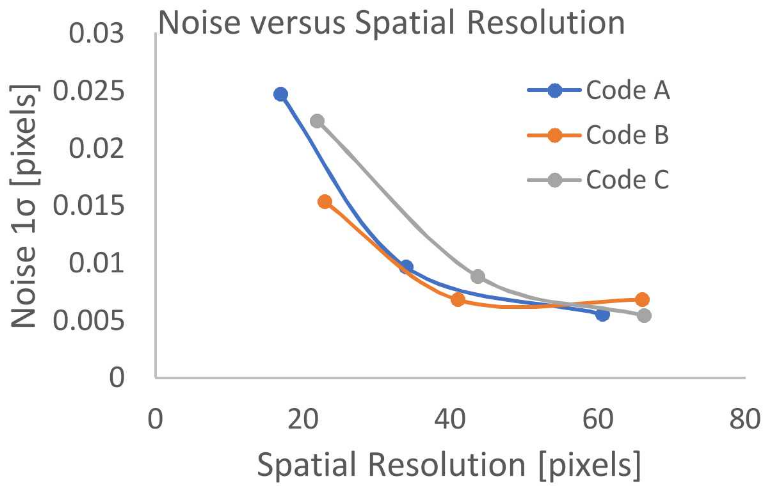
We have a constant strain amplitude image as well.



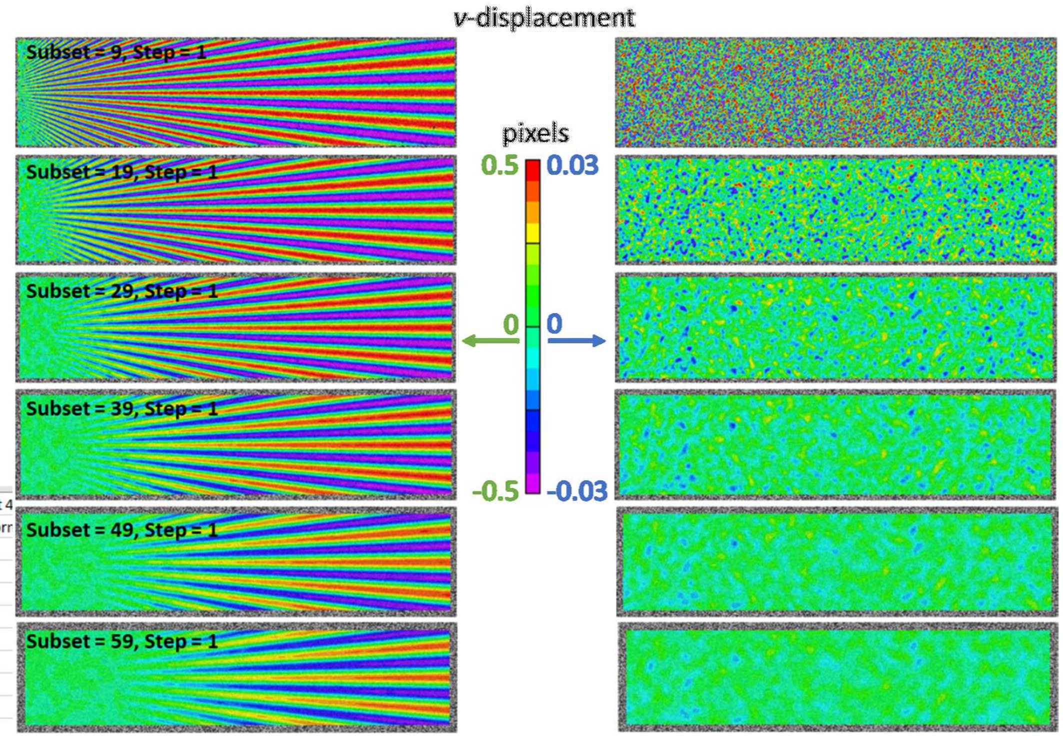


- Avoids the Sample 14 problem of having increasing strain gradients for constant displacement images.
- We have now added Strain Window as a new parameter to vary!

Preliminary results are promising. Need to define submission parameters.



Row 250	Subset 9	Subset 9	Subset 19	Subset 19	Subset 29	Subset 29	Subset 39	Subset 39	Subset 49	Subset 4
Pixel	v-Noise	v-deform	v-Noise	v-deform	v-Noise	v-deform	v-Noise	v-deform	v-Noise	v-deforr
1	NaN	NaN								
2	NaN	NaN								
...										
25	0.0015	0.055482	etc.							
26	-0.0025	0.064797								
...										
2000	NaN	NaN								



- Simple submission of the center row results at 6 subset sizes.
- Includes the noise results.
- Sample results from 3 codes shown here.
- Need to define parameters for VSG for that submission. Ideas are welcome!
- Request “New 2D Challenge” document to enter discussion.

Do we need any “blind” images based on Sample 14?

Discuss!

Stereo-DIC Challenge are available on Google Drive.

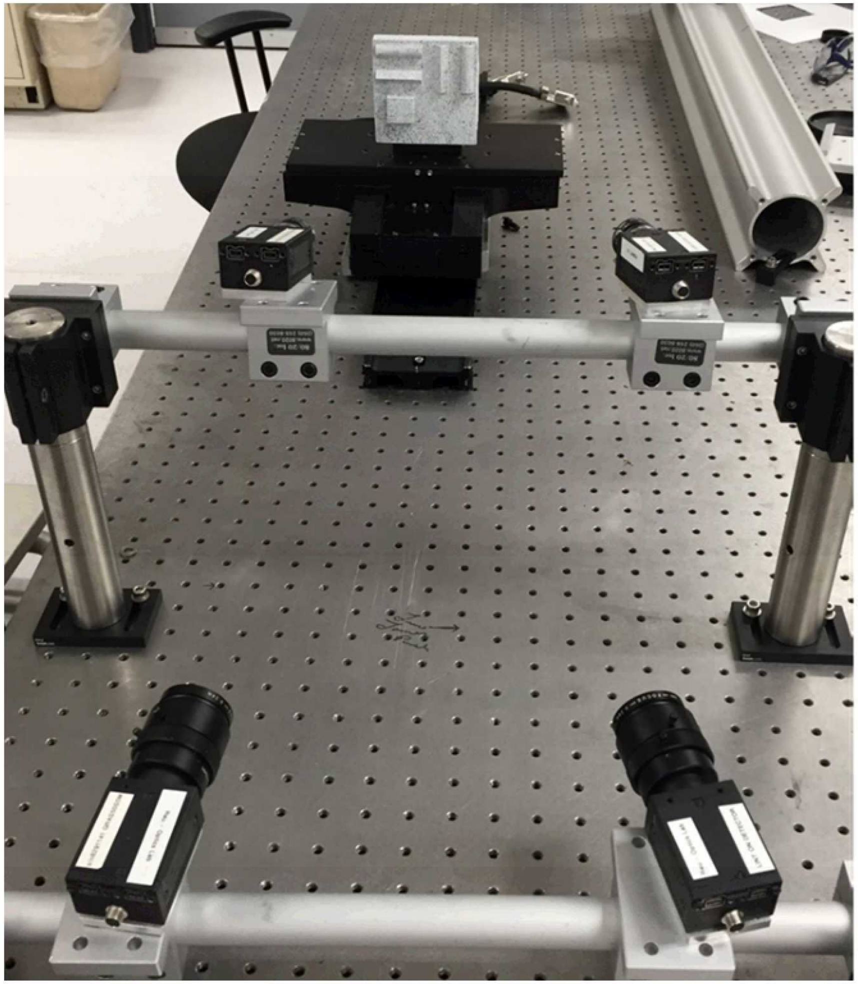
Challenge Set Name	Description	Method of Creation
StereoSample1 - Experiment StereoSample1&2 - Sim Cal	Translation of sample with known dimension. Includes calibration and translation images for a 16-mm and 35-mm stereo-system. Calibration 14×10-10mm	Experimental
StereoSample2 - Simulated StereoSample1&2 - Sim Cal	Simulated translation of plate with known dimensions. Includes calibration and translation images for a 16-mm and 35-mm stereo-system.	Balcaen Simulator
StereoSample3 - Experiment StereoSample3&4 - Sim Cal	D-Specimen tensile test. Calibration 14x10-7mm	Experimental
StereoSample4 - Simulated StereoSample3&4 - Sim Cal	D-Specimen simulated from FE displacement field	Balcaen Simulator
StereoSample5 - Experiment	Tensile specimen with “dummy” region. Calibration 12×9-3.5mm	Experimental
TelecentricSample6 - Experiment	Tensile specimen with telecentric lens. Opposite side to StereoSample5 results.	Experimental

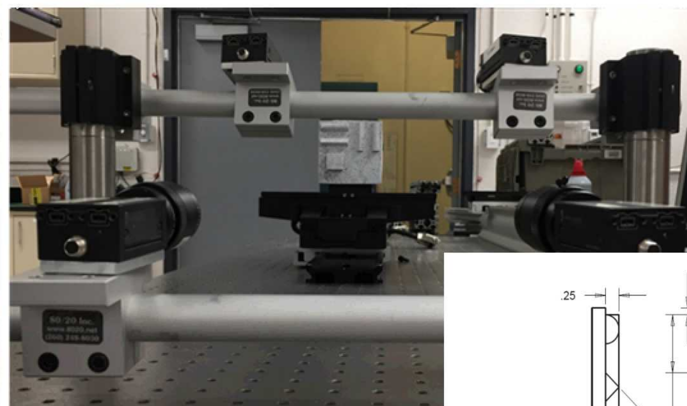
Balcaen R, Wittevrongel L, Reu PL, Lava P, Debruyne D (2017) Stereo-DIC Calibration and Speckle Image Generator Based on FE Formulations. Exp Mech 57 (5):703-718. doi:10.1007/s11340-017-0259-1

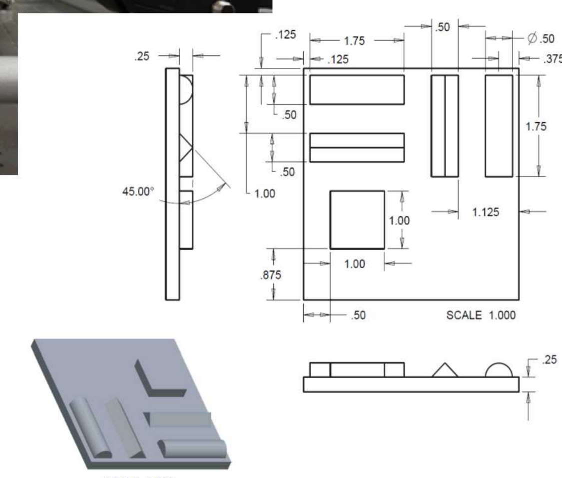
Images available at:

https://drive.google.com/open?id=1uLZdQscdt3pWVwNZU7HBaCxNlUx7ByJb

STEREO-Rigid body motion experimental setup.





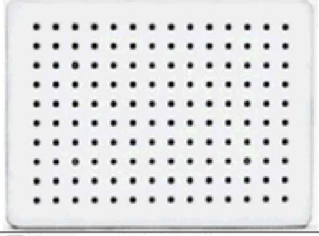
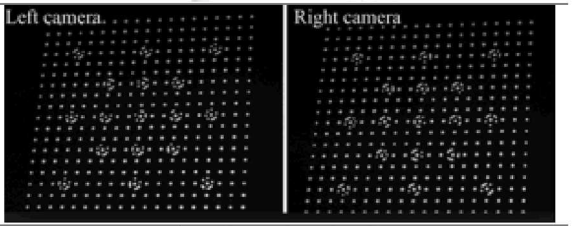
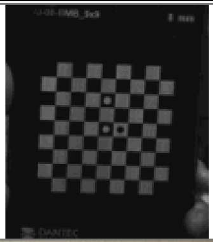
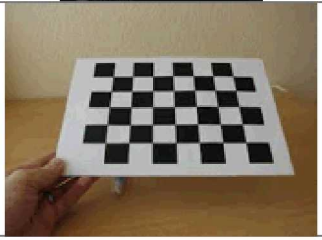


Part was measured via:

- CMM
- Laser scanner

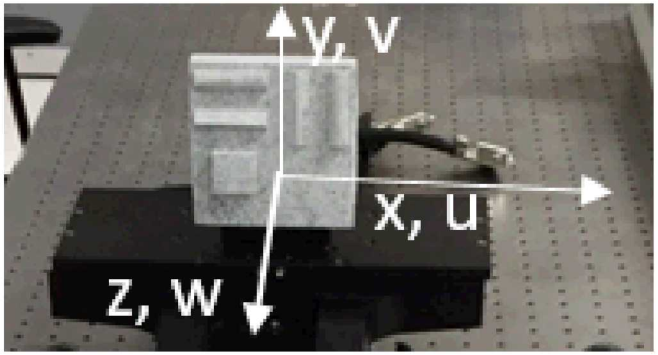
Calibration (with many extra images) were taken according to manufacturers directions.

- Generally followed each manufacturers procedures
- Extra images available if unhappy with some of the images.
- Hand-held all targets
- Everyone should be able to work with one of these image sets!

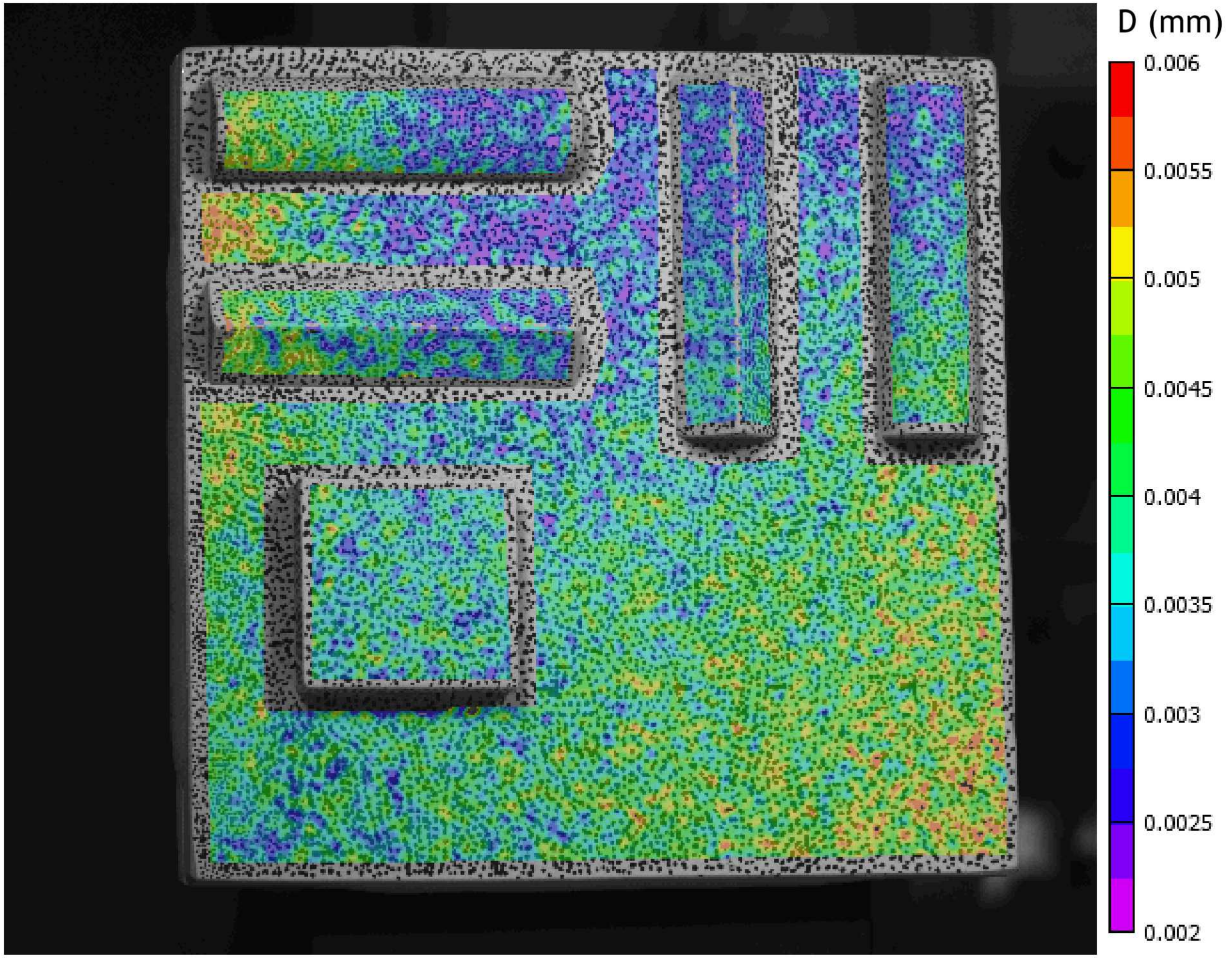
Vendor	Calibration Board
Basic Calibration target: 3 special dots Correlated Solutions, MatchID, and… Exp. images: DotGrid10-mm.zip Sim. images: SimDotCal-14x10-10mm.zip	
3D target with dots at 2 levels LaVision Exp. images: LaVision106-10.zip Simulated images: SimTwoLevelCal10mm2.2Dia2mmLevel.zip	
Coded calibration targets GOM/Trilion Exp. images: GOMCP20MV90x72.zip Sim. images: No simulated images.	
Grid Target Dantec Exp. images: DantecAI-08-BMB9x9-8mm.zip Sim. Images: No simulated images.	
Standard checkerboard pattern CorreliSTC Exp. images: Experimental not imaged. Sim. images: SimCheckerBoardCal.zip	

18-translated images with known displacements. In-Plane and out-of-plane.

Step	Filename 16-mm	Filename 35-mm	W Mean (mm)	StDev (nm)	U Mean (mm)	StDev (nm)
1	Step01 00,00-sys1-0000_0.tif	Step01 00,00-0000_0.tif	0	6.76	0	7.01
2	Step02 00,-10-sys1-0000_0.tif	Step02 00,-10-0000_0.tif	10	6.16	0	7.69
3	Step03 00,-20-sys1-0000_0.tif	Step03 00,-20-0000_0.tif	20	6.21	0	6.30
4	Step04 00,10-sys1-0000_0.tif	Step04 00,10-0000_0.tif	-10	6.12	0	7.67
5	Step05 00,20-sys1-0000_0.tif	Step05 00,20-0000_0.tif	-20	6.33	0	6.74
6	Step06 10,00-sys1-0000_0.tif	Step06 10,00-0000_0.tif	0	6.83	-10	4.91
7	Step07 20,00-sys1-0000_0.tif	Step07 20,00-0000_0.tif	0	7.27	-20	5.71
8	Step08 -10,00-sys1-0000_0.tif	Step08 -10,00-0000_0.tif	0	6.79	10	6.53
9	Step09 -20,00-sys1-0000_0.tif	Step09 -20,00-0000_0.tif	0	7.37	20	5.69
10	Step10 10,10-sys1-0000_0.tif	Step10 10,10-0000_0.tif	-10	4.57	-10	5.99
11	Step11 20,20-sys1-0000_0.tif	Step11 20,20-0000_0.tif	-20	25.19	-20	14.65
12	Step12 -10,-10-sys1-0000_0.tif	Step12 -10,-10-0000_0.tif	10	6.43	10	7.65
13	Step13 -20,-20-sys1-0000_0.tif	Step13 -20,-20-0000_0.tif	20	6.54	20	6.10
14	Step14 10,-10-sys1-0000_0.tif	Step14 10,-10-0000_0.tif	10	6.08	-10	5.70
15	Step15 20,-20-sys1-0000_0.tif	Step15 20,-20-0000_0.tif	20	6.45	-20	5.14
16	Step16 -10,10-sys1-0000_0.tif	Step16 -10,10-0000_0.tif	-10	5.01	10	6.29
17	Step17 -20,20-sys1-0000_0.tif	Step17 -20,20-0000_0.tif	-20	6.07	20	5.99
18	Step18 00,00-sys1-0000_0.tif	Step18 00,00-0000_0.tif	0	7.59	0	6.36

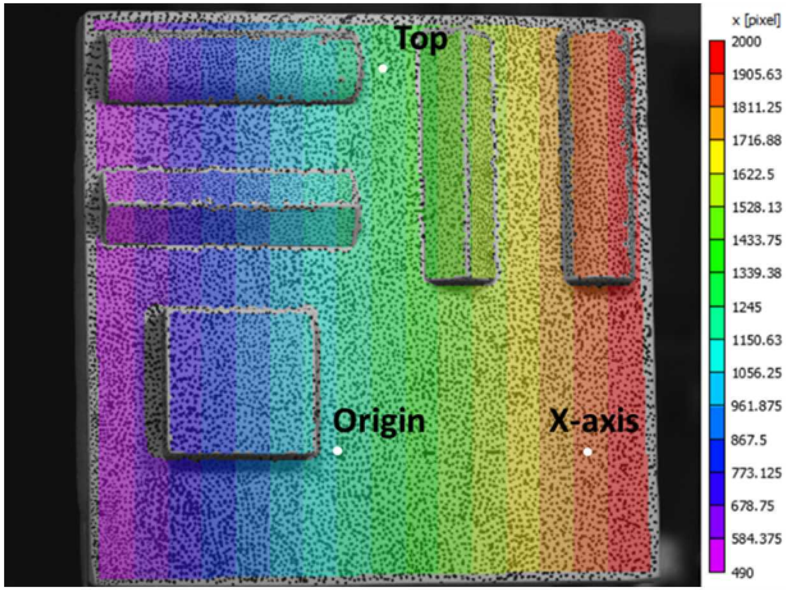


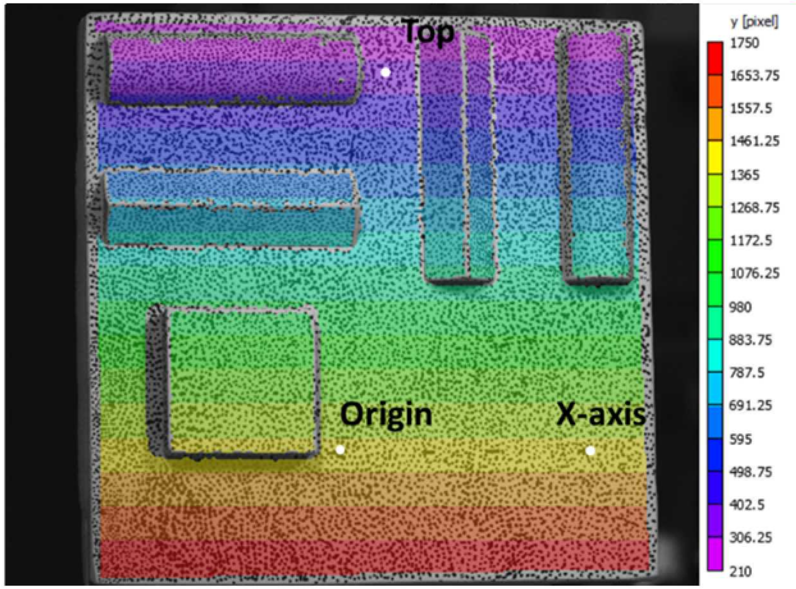
Return to home had very little offset from the start indicating a stable experiment.



System 1 results (35-mm) Shown

Common coordinate system is needed for comparison. We need to discuss this.





	System 1 35-mm				System 2 16-mm				Global Coordinates			System 1 Fit			System 2 Fit		
Point Location	Xs1 [pix]	Ys1 [pix]	Xs2 [pix]	Ys2 [pix]	Xs1 [pix]	Ys1 [pix]	Xs2 [pix]	Ys2 [pix]	X [mm]	Y [mm]	Z [mm]	X [mm]	Y [mm]	Z [mm]	X [mm]	Y [mm]	Z [mm]
Origin	1164	1409	1150.901	1392.114	1092.909	1395.507	1193.652	1354.671	0	0	0	0.168159	-0.03816	0	0.168764	-0.03765	0
X	1855	1403	1843.909	1395.129	1738.654	1382.73	1859.497	1370.702	45	0	0	44.8353	-0.01943	-1.14E-13	44.8329	-0.0156	0
Top	1306	312	1345.901	294.1977	1312.953	317.6764	1267.083	268.0739	11	70	0	10.9966	70.0576	-1.14E-13	10.9983	70.0532	0

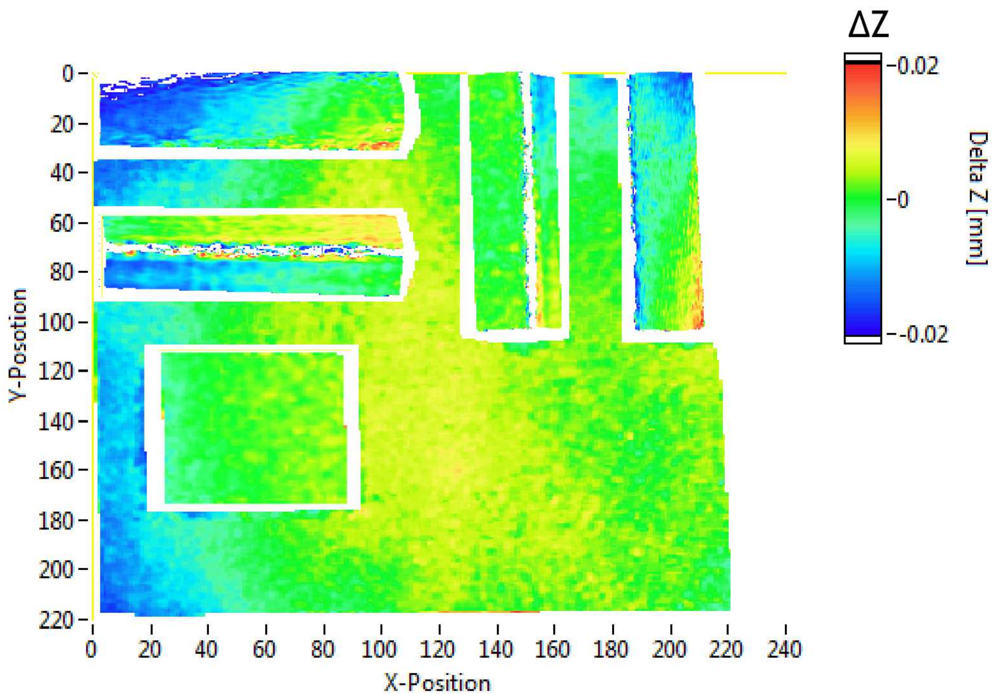
- System 1 reference image pixel coordinates image (x_{s1}, y_{s1}) will be provided for 3-points in System 1 (35-mm).
- Chosen at the integer pixel location nearest the integer Global coordinates.
- System 1 cross-correlation found via traditional methods.

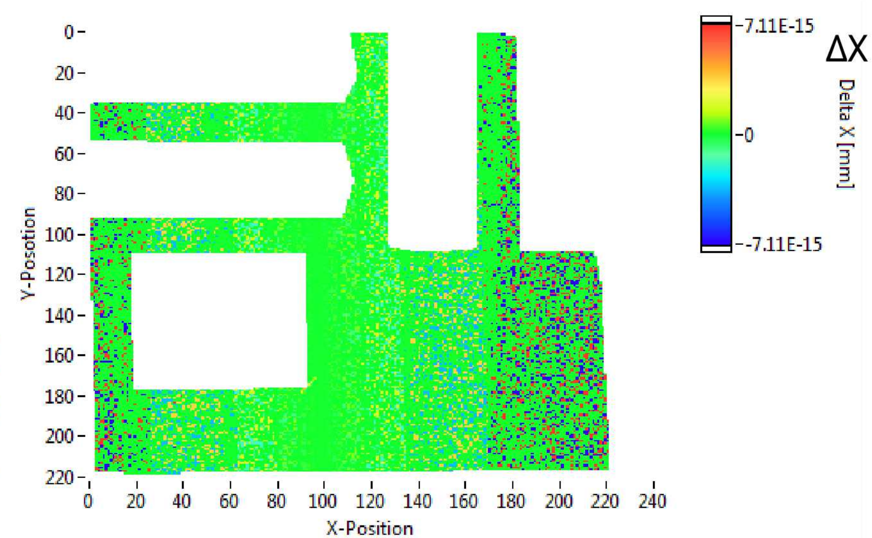
System 1 35-mm Transform				System 2 16-mm Transform			
0.99917	0.002924	0.040622	27.1137	0.998135	-0.00034	0.061037	18.4342
0.001878	0.99305	-0.11768	-49.0985	-0.01246	0.977778	0.209274	77.7759
-0.04068	0.117655	0.992221	614.207	-0.05975	-0.20965	0.97595	257.103
0	0	0	1	0	0	0	1

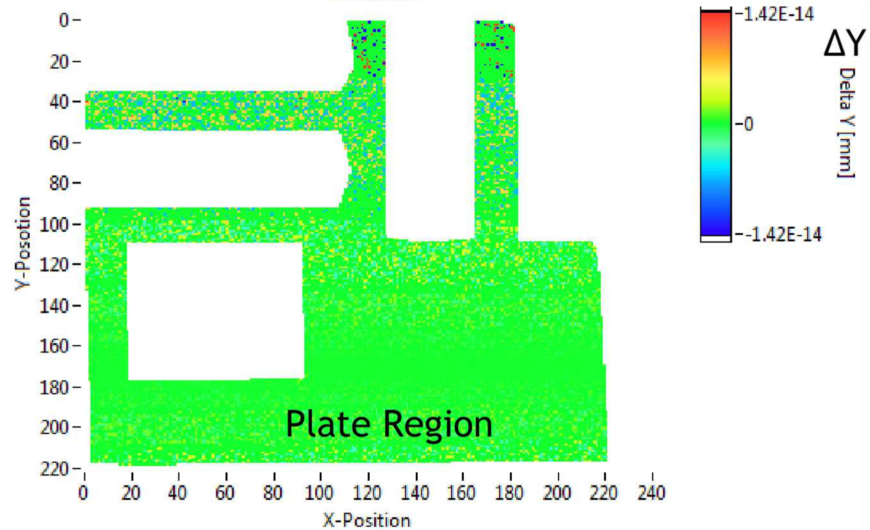
- Triangulate the 3 points and do a best fit to the global coordinates. Not a perfect fit. This transformation goes from any arbitrary coordinates to a single Global coordinate.
- Rigid-body-removal can also be handled by adding the u, v motions at other positions and then fitting.
- Or: This transformation will be used for all steps after to put into a single global coordinate system.
- System 2 pixel coordinates found by correlation with System 1 coordinates. This was done via multi-system in Vic at this point. Could be done with 2D correlation (lens distortion issues?). Find System 2 coordinate transform to Global Coordinates.

Comparison is done by interpolating onto the same data locations. (System 1 to System 2)

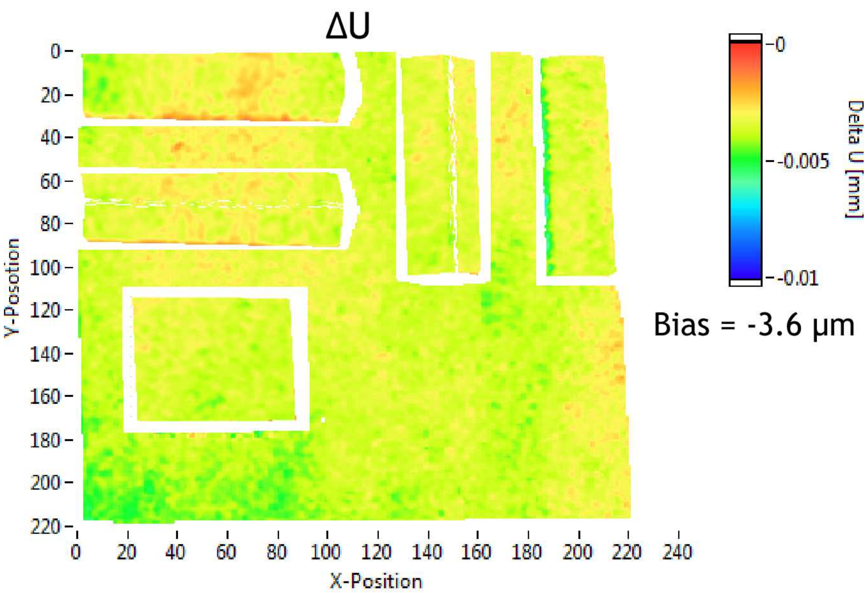
- We now have a 1 pixel spacing data for both Systems in a Global Coordinate system.
- We have a dense grid of X, Y and Z data (or U, V, W) that we need to align for comparison.
- System 1 used as a baseline and System 2 interpolated in X, Y and Z (Linear) to get aligned data points.
- For X and Y – Machine precision errors only.
- For Z only lens distortions remain.

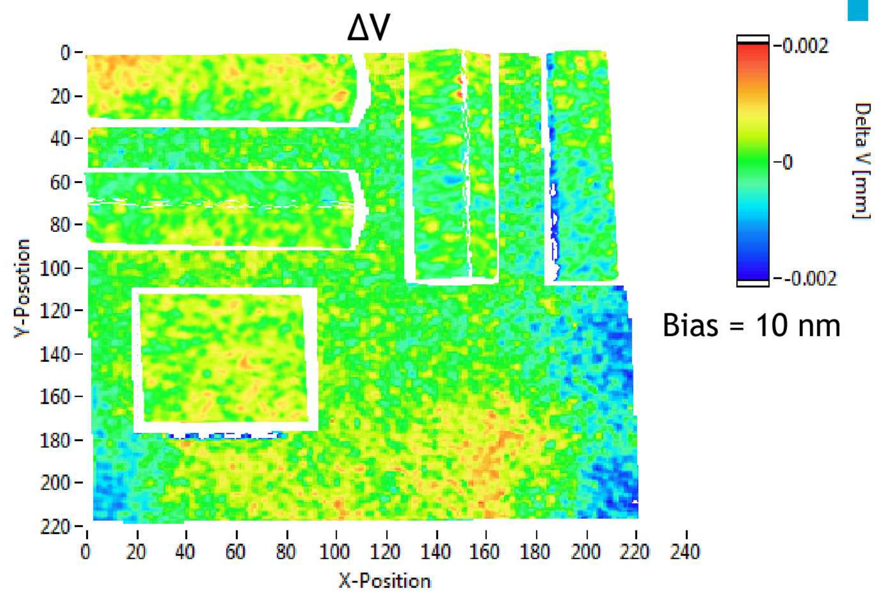




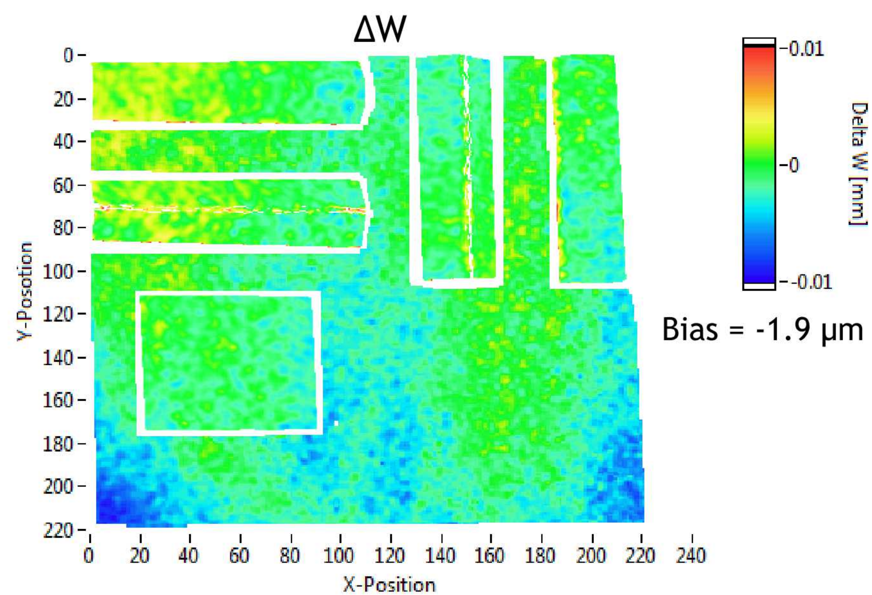


Step 4 Comparison: W = -10 mm, U = 0 mm

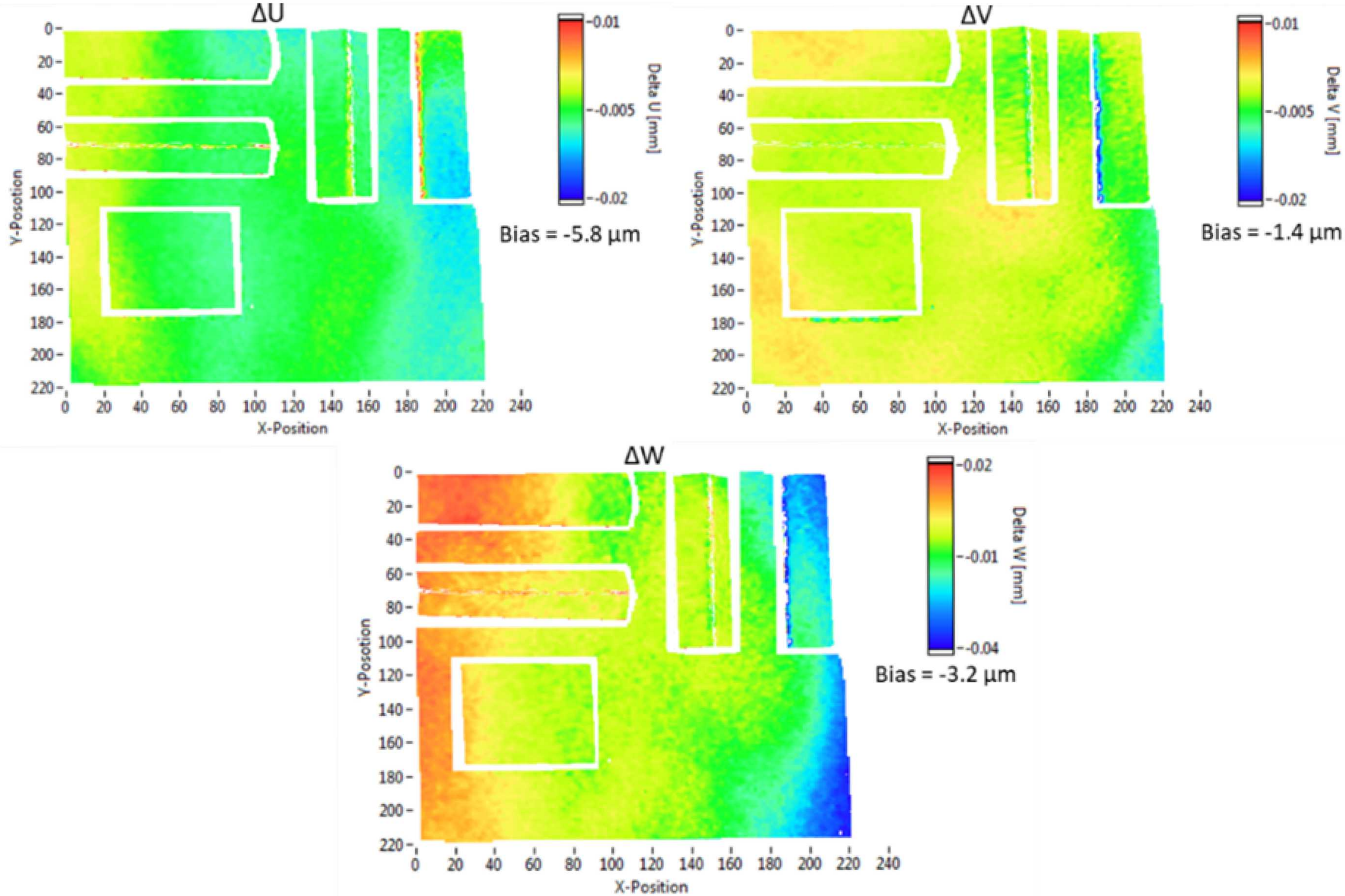




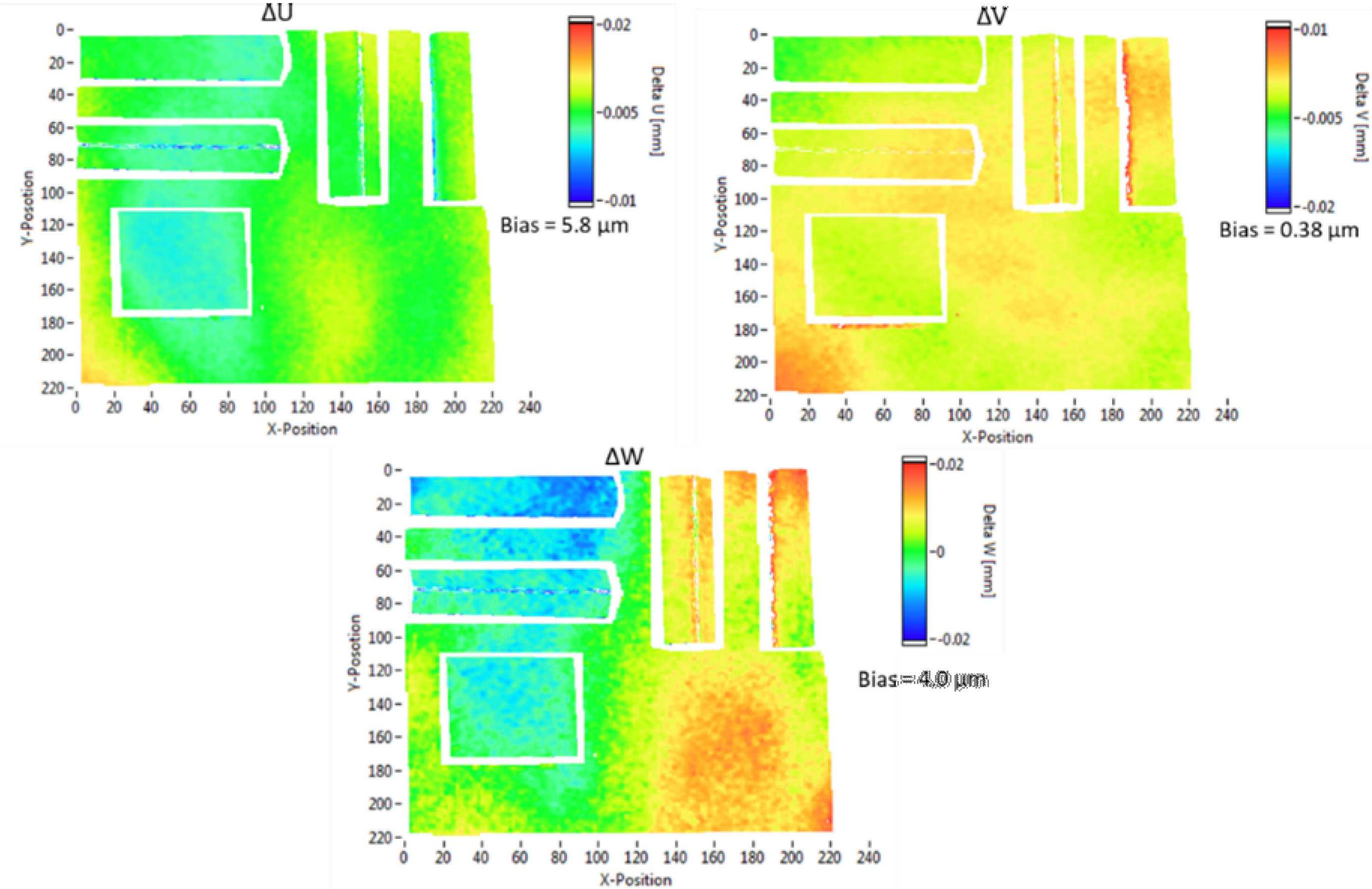
- Point by point comparison of System 1 to System 2 translation results.
- Bias indicates offset between the systems for the entire flat plate region.



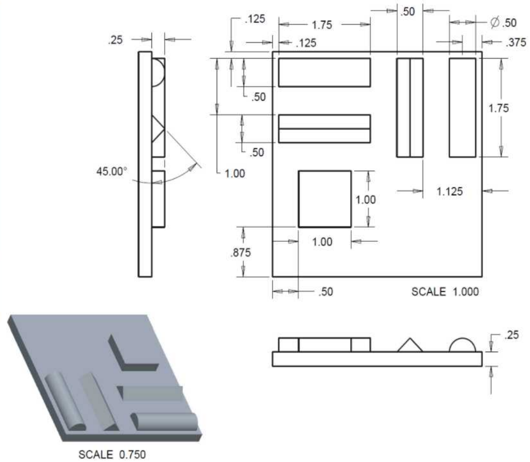
Step 11 Comparison: W = -20 mm, U = -20 mm

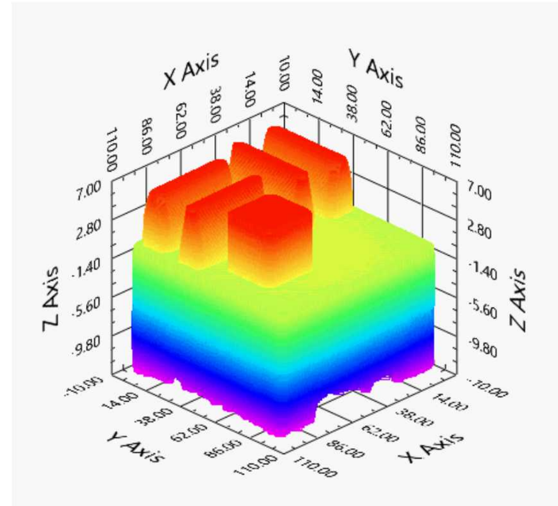


Step 13 Comparison: W = 20 mm, U = 20 mm



A laser scanner metrology system was used to measure the shape of the object.



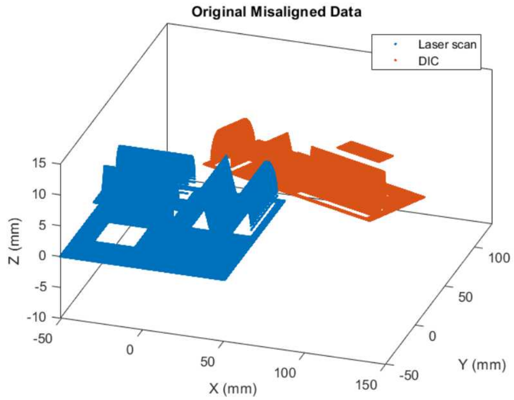


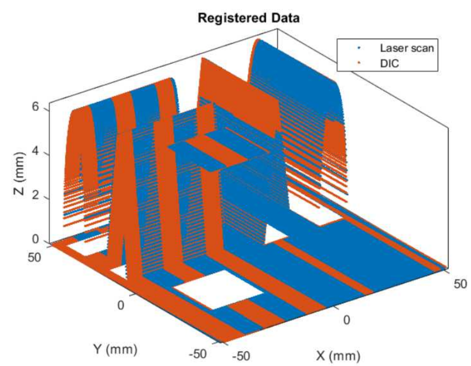
Faro Edge Laser Scan

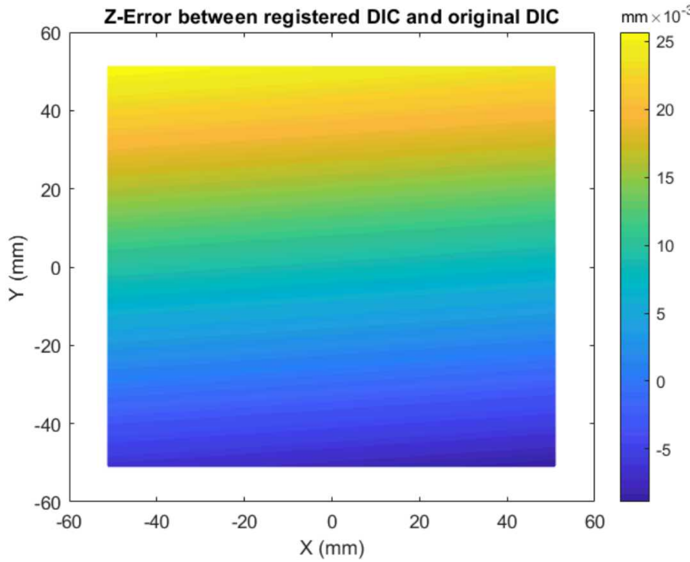
Laser Line Probe Specifications

Accuracy: ±25µm (±.001in)
Repeatability: 25µm, 2σ (.001in)
Stand-off: 115mm (4.5in)
Depth of Field: 115mm (4.5in)
Effective Scan width: Near Field 80mm (3.1in), Far Field 150mm (5.9in)
Points per line: 2,000 points/line
Minimum Point Spacing: 40µm (.0015in)
Scan Rate: 280 frames/second, 280fps x 2,000 points/line = 560,000 points/sec
Laser: Class 2M
Weight: 485g (1.1lb)

ICP algorithm didn’t work very well for laser scan data.







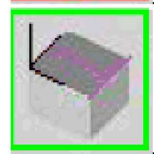
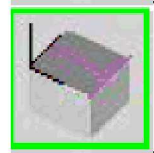
Original Transformation Matrix					Recovered Transformation Matrix			
-0.9981	-0.0261	0.0564	0		-0.9985	-0.0084	0.0549	0
0.031	-0.9955	0.0891	0		0.0133	-0.9959	0.0897	0
0.0539	0.0906	0.9944	0		0.0539	0.0903	0.9945	0
58.854	78.213	0.1	1		59.1656	78.5749	0.0418	1

A Coordinate Measurement Machine (CMM) was also used to get heights and angles.

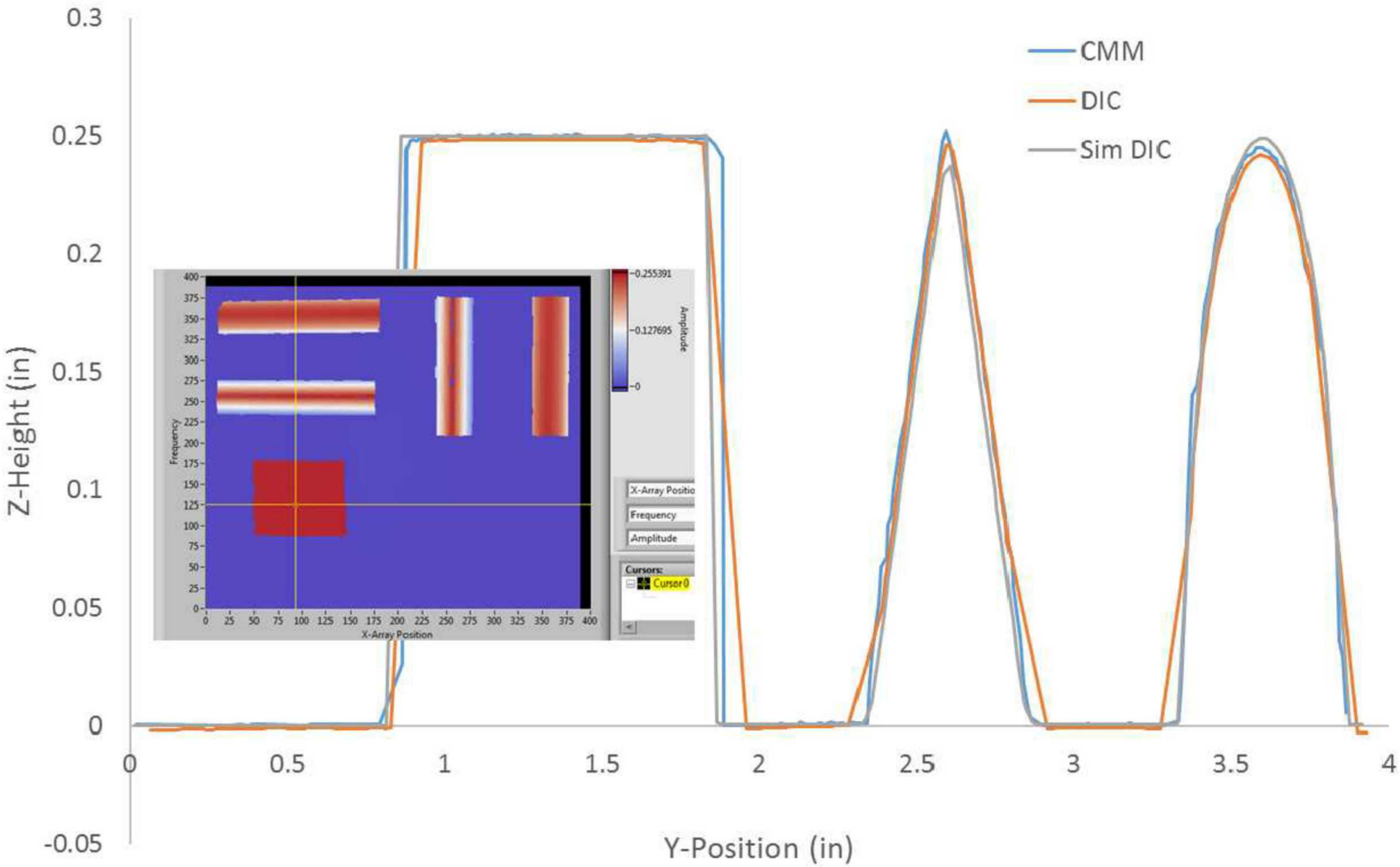
ZEISS Calypso

Measurement Plan Paul Farias - Test Plate	Date April 27, 2017	
Drawing No. * drawingno *	Time 8:03:04 am	Order
Operator Master	CMM Simulation	Incremental Part Number 2

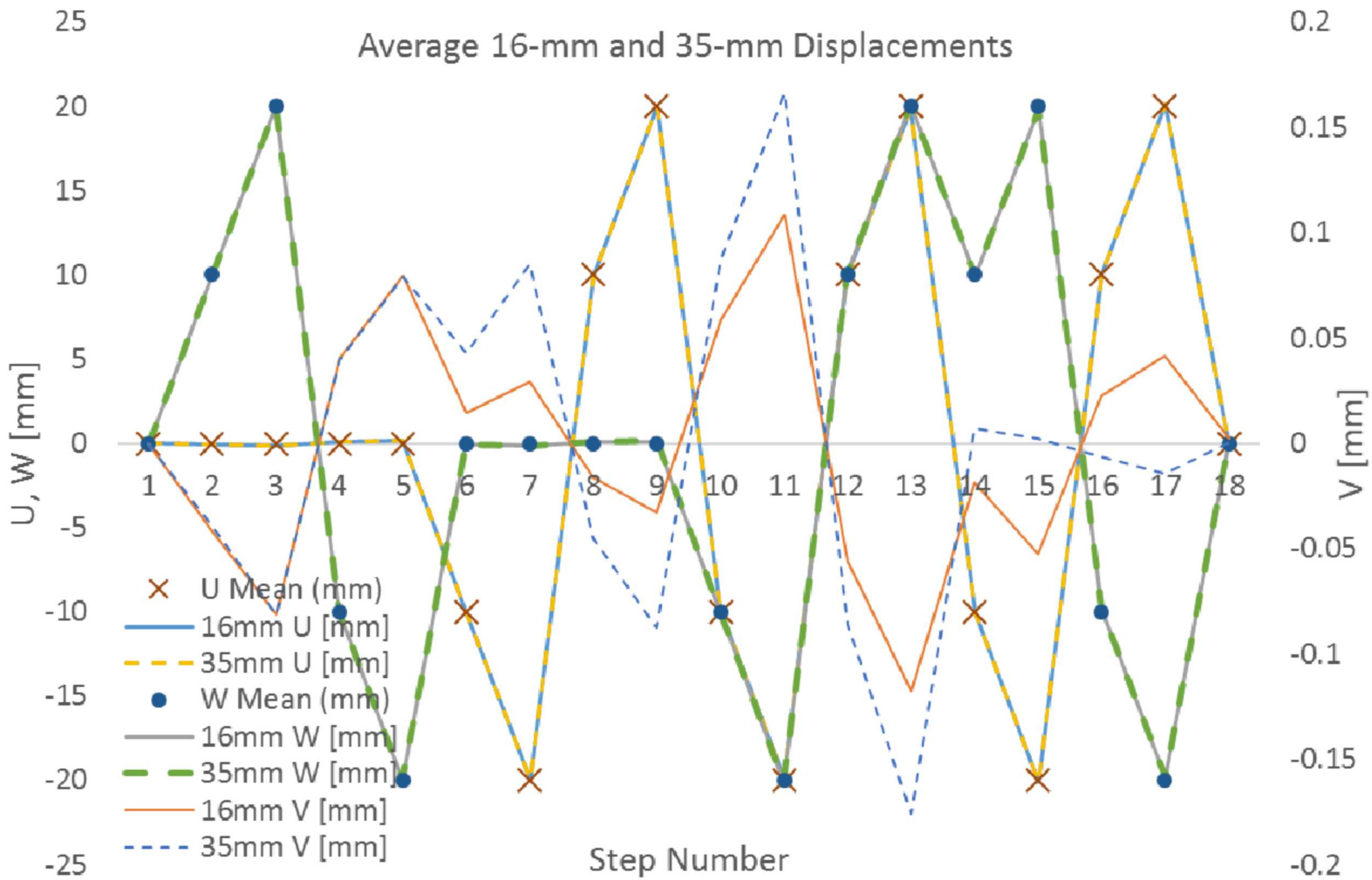
- Heights, angles and radius are measured.
- There are quite a few things we can compare to.

	Horizontal Triangle - Angle	90.1436	90.1426
	Horizontal Cylinder - Right	3.8917	3.8917
	Horizontal Cylinder - Left	2.1195	2.1195
	Horizontal Cylinder - Diameter	0.4959	0.4959

How do we compare to the laser scan data? Line cuts are one approach.

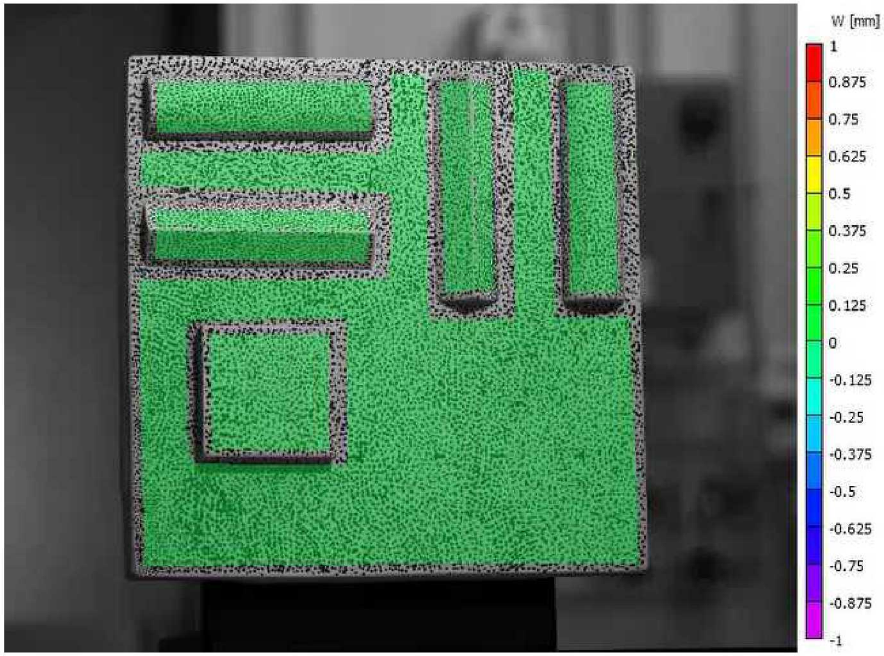


Sample 1 Translation results

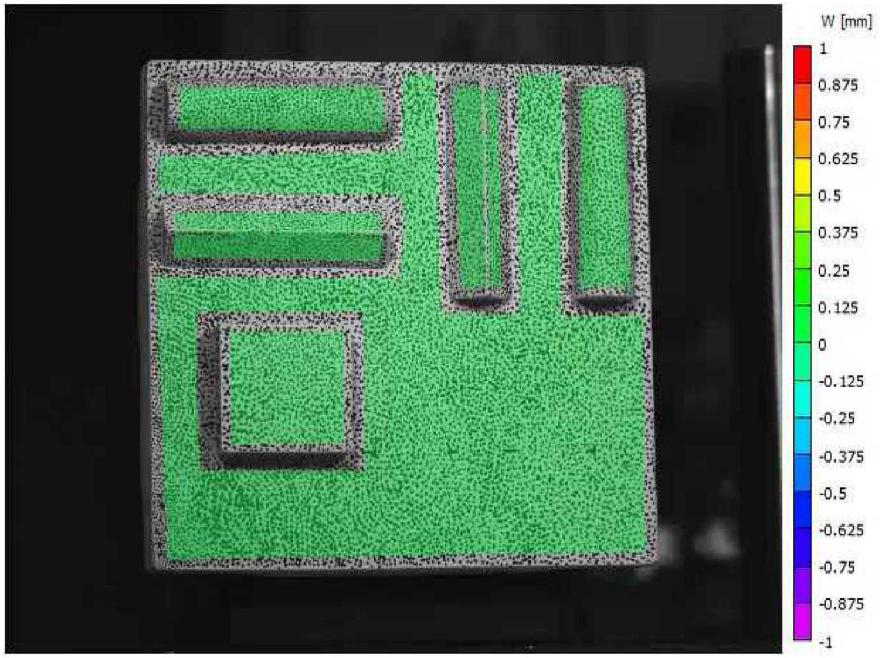


Issues with the first data sets

Old Image Set Firewire 5-MPixel

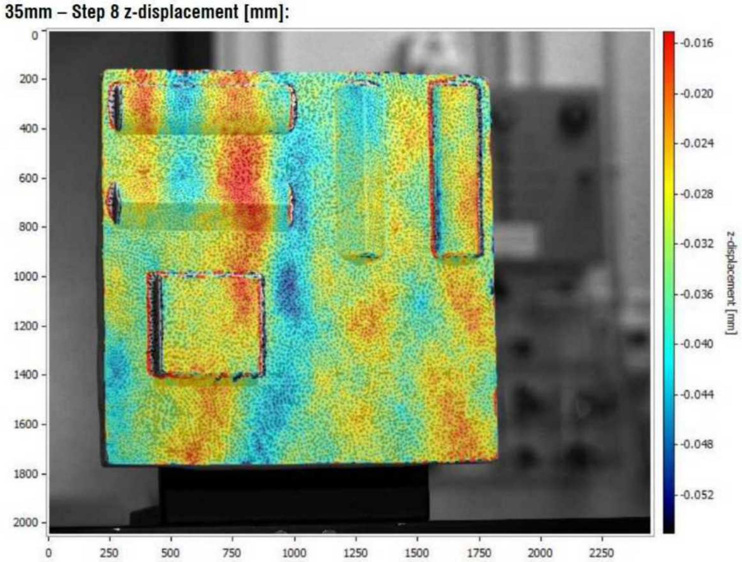


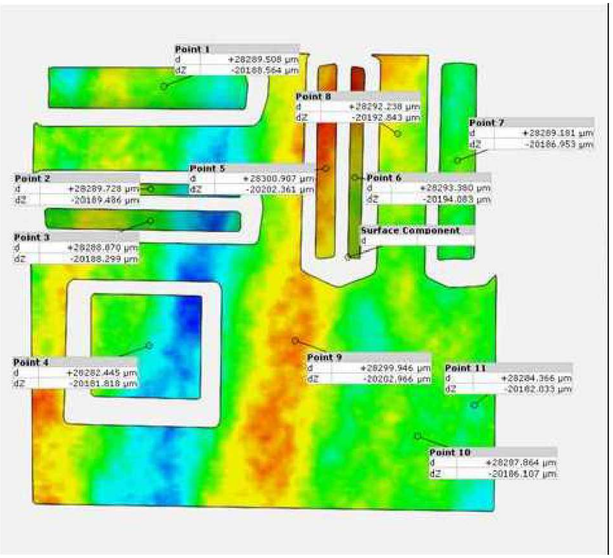
New Image Set Sony 5-MPixel

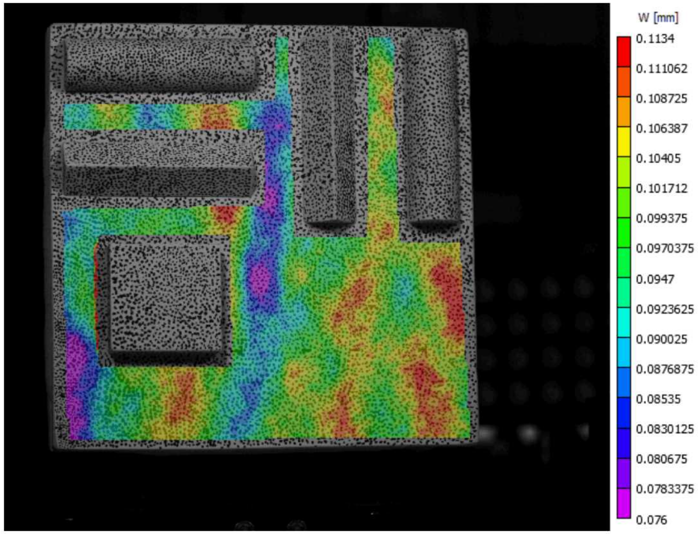


Relax and watch the moving plate…

Results from the codes

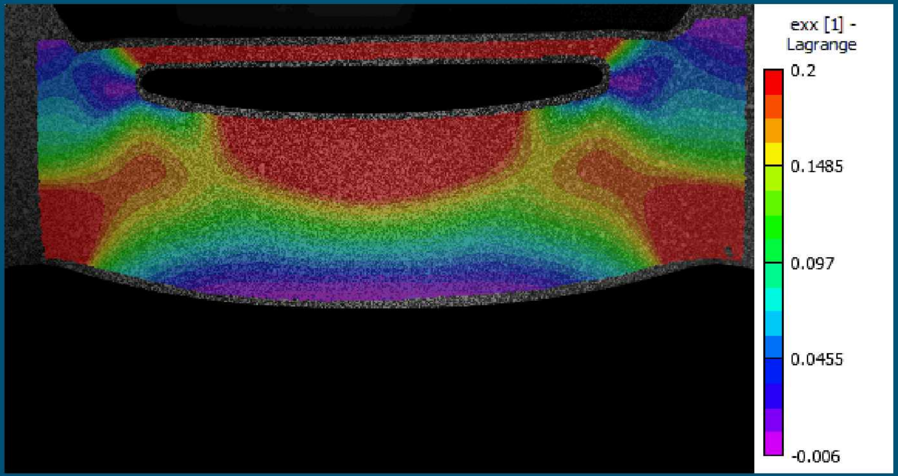


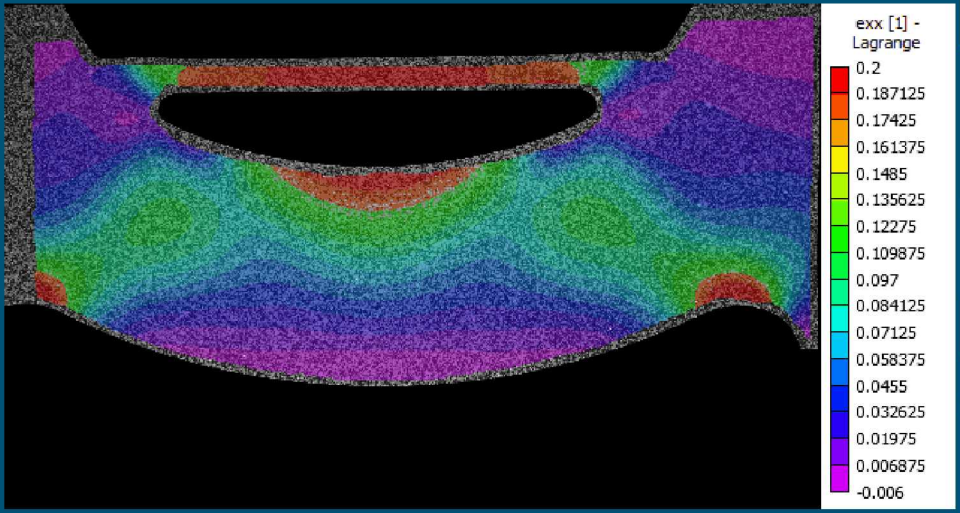




- Banding showed up in all codes and was stationary
- Is this a warped sensor? How would we prove that?

D-Specimen – Experimental and Simulation





DIC experiment