SHADOWSENSE PERFORMANCE REPORT: DE-RATED LEDS

DOCUMENT REVISION HISTORY

Revision	Date	Author	Comments
1.2	Nov\19\2015	Jason Tang-Yuk	Added more trial results
1.1	Oct\5\2015	John La	Re-formatted for release
1.0	Aug\27\2015	Jason Tang-Yuk, Gurinder Singh, Avanindra Utukuri	Created the document

1.0 Objective

ShadowSense technology uses a number of LED emitters which emit an IR light curtain over the touch surface. When any object touches the screen, it casts a pattern of shadows which are detected by our proprietary Shadow Sensors and the position of the touch is triangulated. Over time, it is reasonable to expect that the LEDs will degrade and their optical output will be diminished. This could occur due to the natural degradation over years of use or could be a result of contaminants such as dust that builds up and blocks the LED's light output. LEDs can degrade in a pseudo-random fashion over time as the touch screen is used in operation. Certain LEDs might naturally degrade faster than others based on manufacturing variations resulting in random LEDs degrading over the entire length of the touch screen. Conversely, LEDs might degrade sequentially based on external contamination such as dust. For example, it is conceivable that dust will collect on the bottom surface of the touch screen faster than on the vertical sides and all the LEDs on the bottom surface are obstructed faster over time due to this reason.

The main objective of this experiment is to understand and characterize the performance degradation of the touch screen as the LEDs are de-rated. This experiment characterizes two different types of LED degradation events: pseudo-random (Method-1) and consecutive (Method-2). For the purpose of this experiment, the optical output of a specific LED was reduced by blocking the physical LED with layers of tape. Once LEDs were de-rated a robotic test fixture was used to characterize the performance of the touch screen.

1.1 Equipment

The equipment used during the entire test:

- Baanto SDW656 touch frame with firmware 7.30
- Baanto Dashboard software
- AXYZ CNC machine
- MATLAB
- MATLAB test script

1.2 Setup

A Baanto ShadowSense SDW656W1 touch frame was assembled and tested to ensure that there were no defects with the unit. The configuration parameters were all reset to the default settings through Dashboard. The frame was then put into position for the test on the AXYZ CNC machine (*Figure 1*) and tested. The CNC machine is controlled via a MATLAB script that is able to move the CNC probe and test the touch screen over 1600 evenly spaced positions along the entire surface. The error is then measured as the difference between the true position of the robot and the position being read from the ShadowSense touch frame. *Figure 2* shows the output of the test. The red dots represent the true position of the robot, while the blue line indicates the measured point. In addition there are two heat

maps that are generated that show the error distribution across the entire touch area. One is generated to show the error in the X direction and one is generated to show the error in the Y direction.

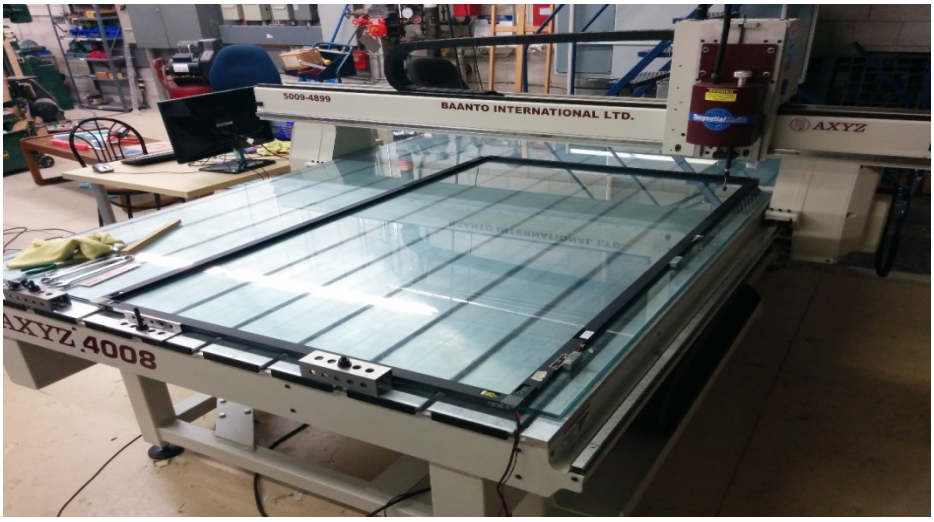


Figure 1: Fault tolerance testing set up on AXYZ CNC machine

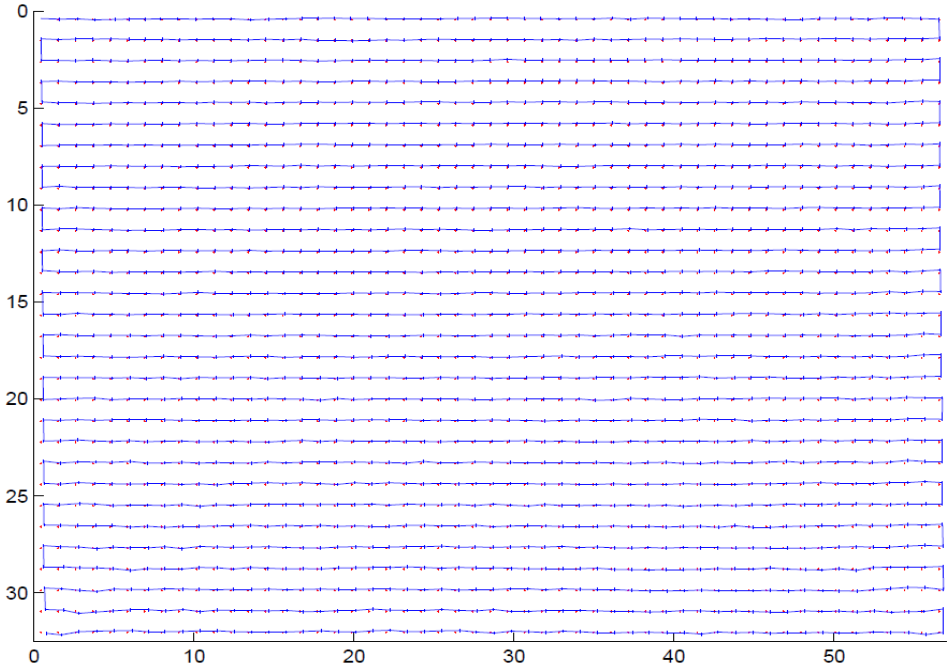


Figure 2: Test pattern for the AXYZ CNC machine for 1600 test points. Axes represent the respective dimensions of the touch frame in inches

1.3 Baseline vs. De-Rated LED Brightness

Figure 3 and *Figure 4* below demonstrate the change in LED power before and after electrical tape has been applied. It can be seen from *Table 1* that on average, the LED's optical brightness has been reduced by more than 95%.

Figure 3: Baseline LED brightness values

Figure 4: 27 LEDs De-rated

Table 1: Difference between LED brightness values of baseline test and 27 consecutive De-rated LED's values

LED number	Brightness LED Values (Baseline)	Brightness Values of 27 De-rated LEDs	% decrease in Brightness of De-rated LED values
32	860	7	99.18
33	873	34	96.10
34	880	42	95.23
35	822	37	95.50
36	809	36	95.55
37	756	26	96.56
38	811	49	93.95
39	731	26	97.10
40	733	44	93.99
41	715	40	94.41
42	726	39	94.63
43	702	35	95.01
44	622	26	95.82
45	613	12	98.04
46	676	21	96.89
47	569	19	96.66
48	651	45	93.09
49	622	20	96.78
50	601	22	96.34
51	551	21	96.19
52	532	3	99.44
53	535	10	98.13
54	537	22	95.90
55	372	12	96.77
56	624	17	97.28
57	679	32	95.29
58	624	10	98.40

2.0 Method 1 – Pseudo-Random LEDs De-Rated

The first set of tests were done to evaluate the performance degradation when pseudo-random LEDs were degraded. Multiple tests were conducted by de-rating 3 additional LEDs each time. This is illustrated in *Figure 5*.

The baseline results of the accuracy test on the AXYZ CNC machine are shown below under "Trial-1 - Baseline Test: 0 LEDs De-rated". The baseline measurements are also shown on two heat maps which show the X and Y accuracy across the entire surface of the frame. Several intermediate results are also shown to establish a pattern.

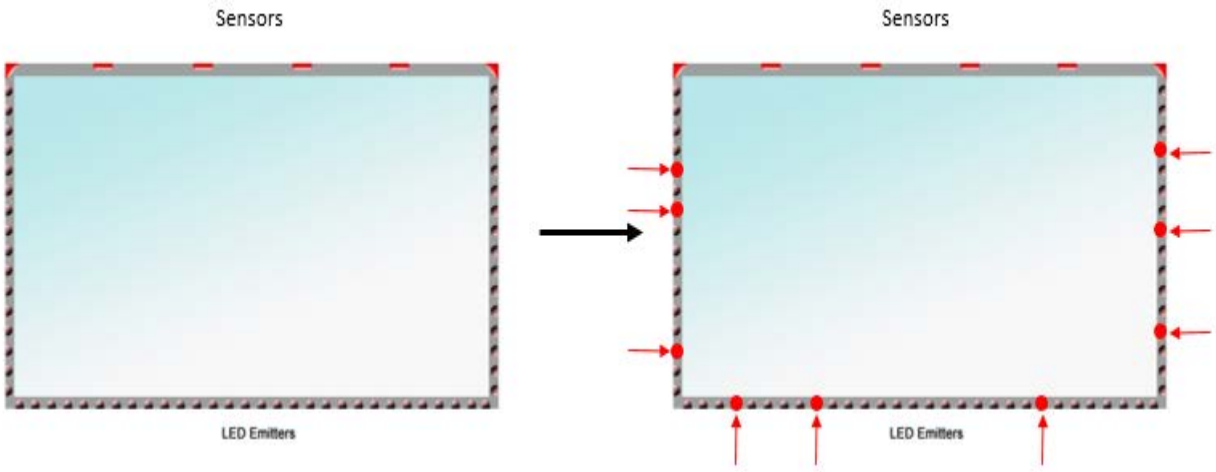
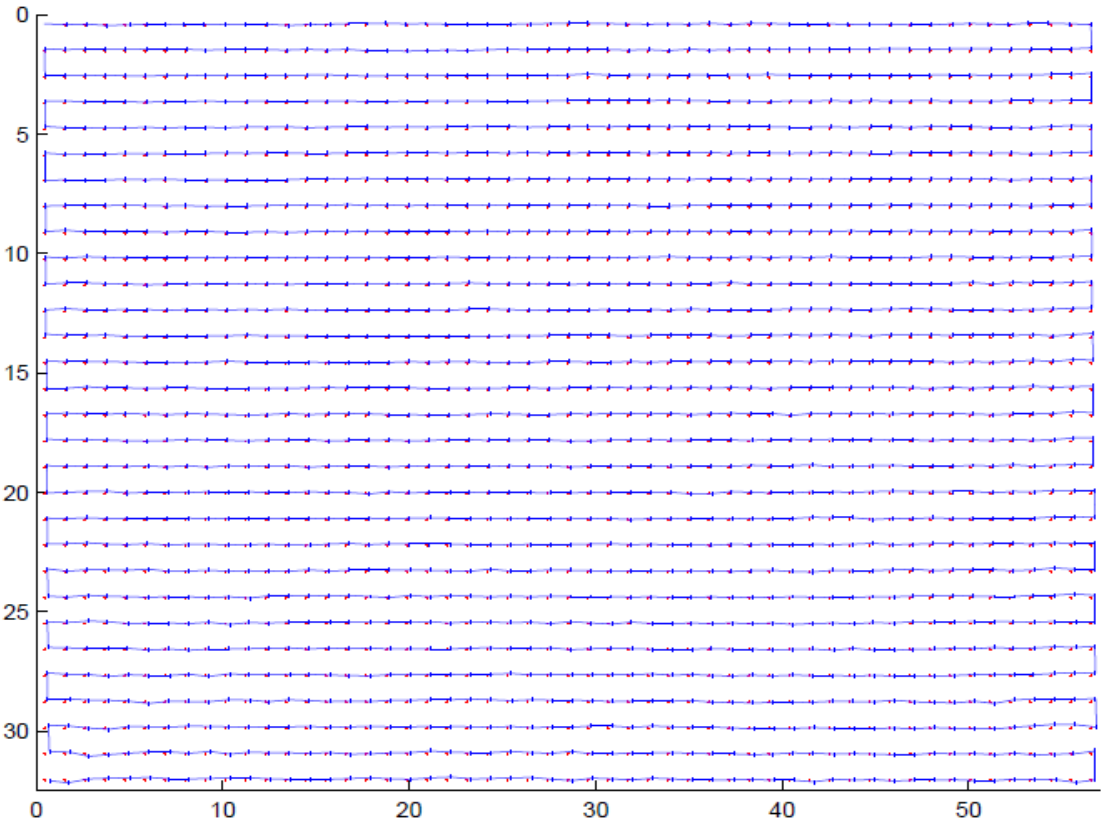


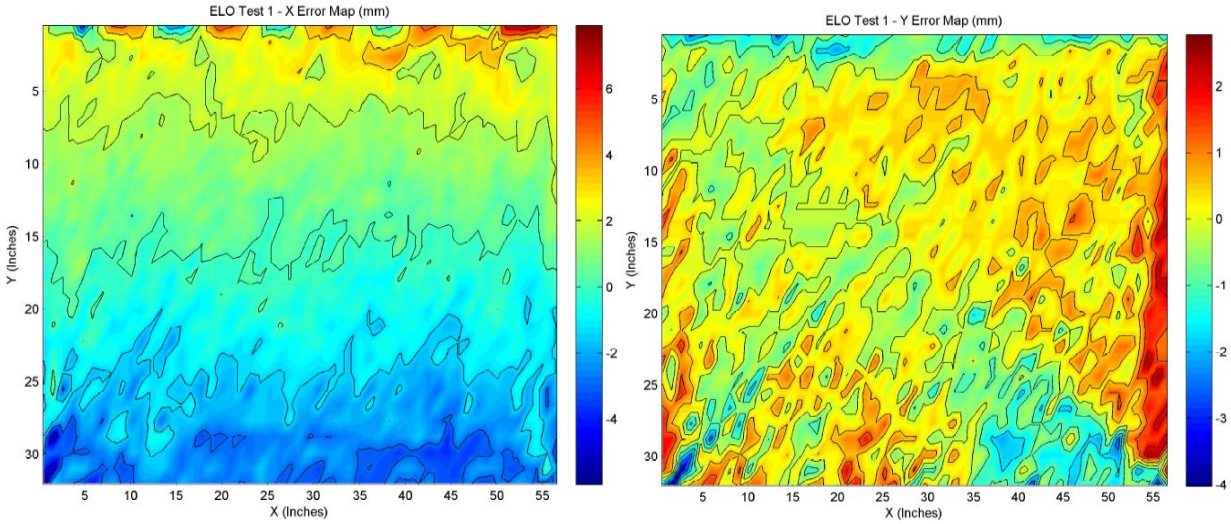
Figure 5: De-rating 3 non-consecutive IR LEDs each test from the respective light bars.

The following set of trials show a sub-set of results that were taken during the tests. Certain test results have been omitted because they did not show any significant deviation from the norm and also for the sake of brevity.

Trial-1 -- Baseline Test: 0 LEDs De-rated:

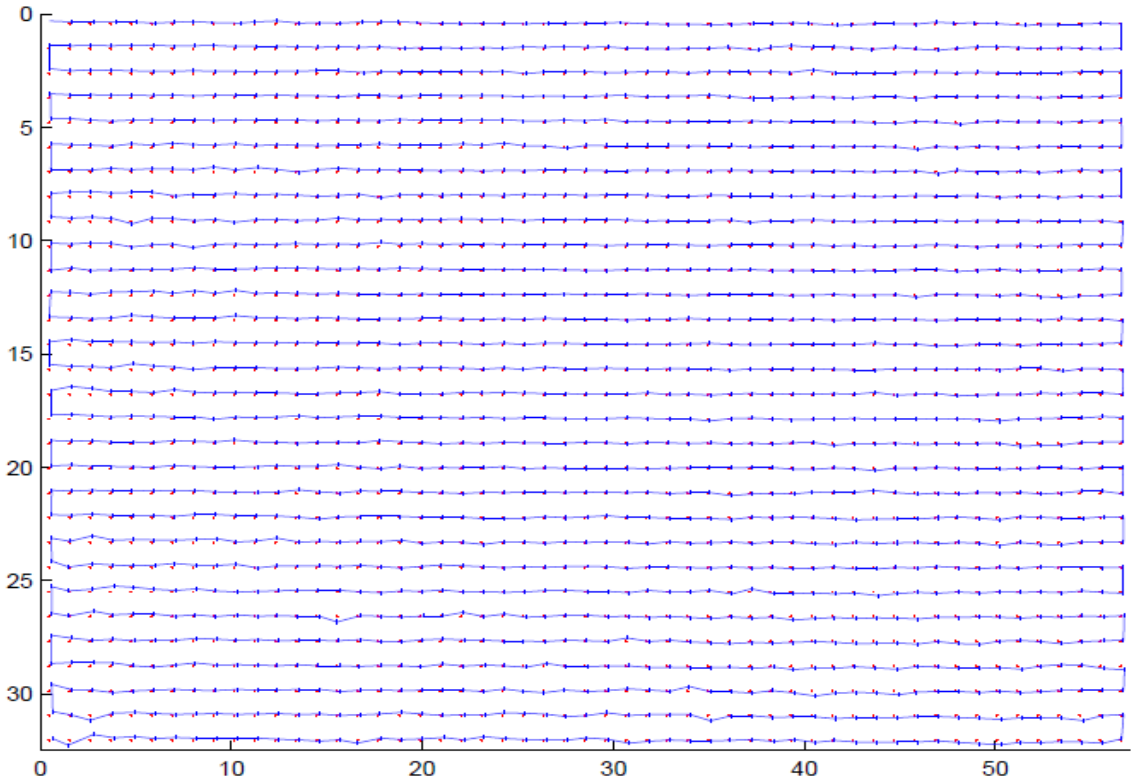
Error at 90: 3.061mm	
Missed Data Points in x:	**0**
Missed Data Points in y:	**0**
Mean Total Error: 1.676mm	
Mean X Error: 1.474mm	
Mean X Error without Nulls:	**1.474mm**
Mean Y Error: 0.5965mm	
Mean Y Error without Nulls:	**0.5965mm**

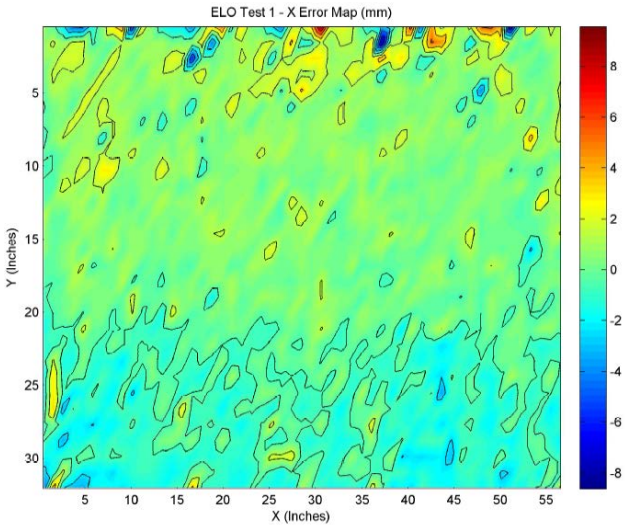


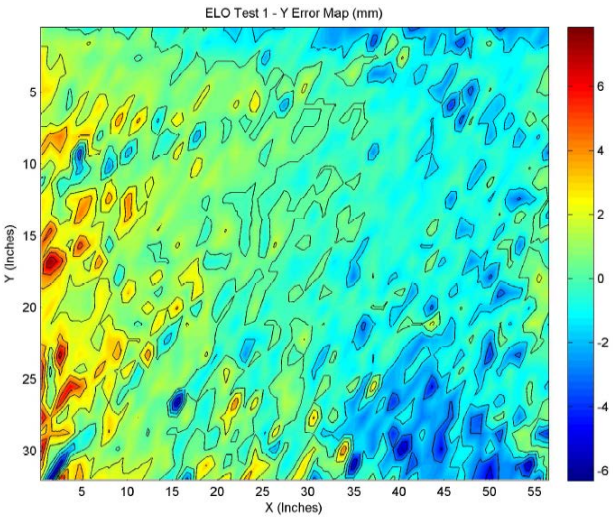


Trial-4 -- 27 LEDs De-rated:

Error at 90: 3.186mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.652mm
Mean X Error: 0.9038mm
Mean X Error without Nulls: 0.9038mm
Mean Y Error: 1.202mm
Mean Y Error without Nulls: 1.202mm

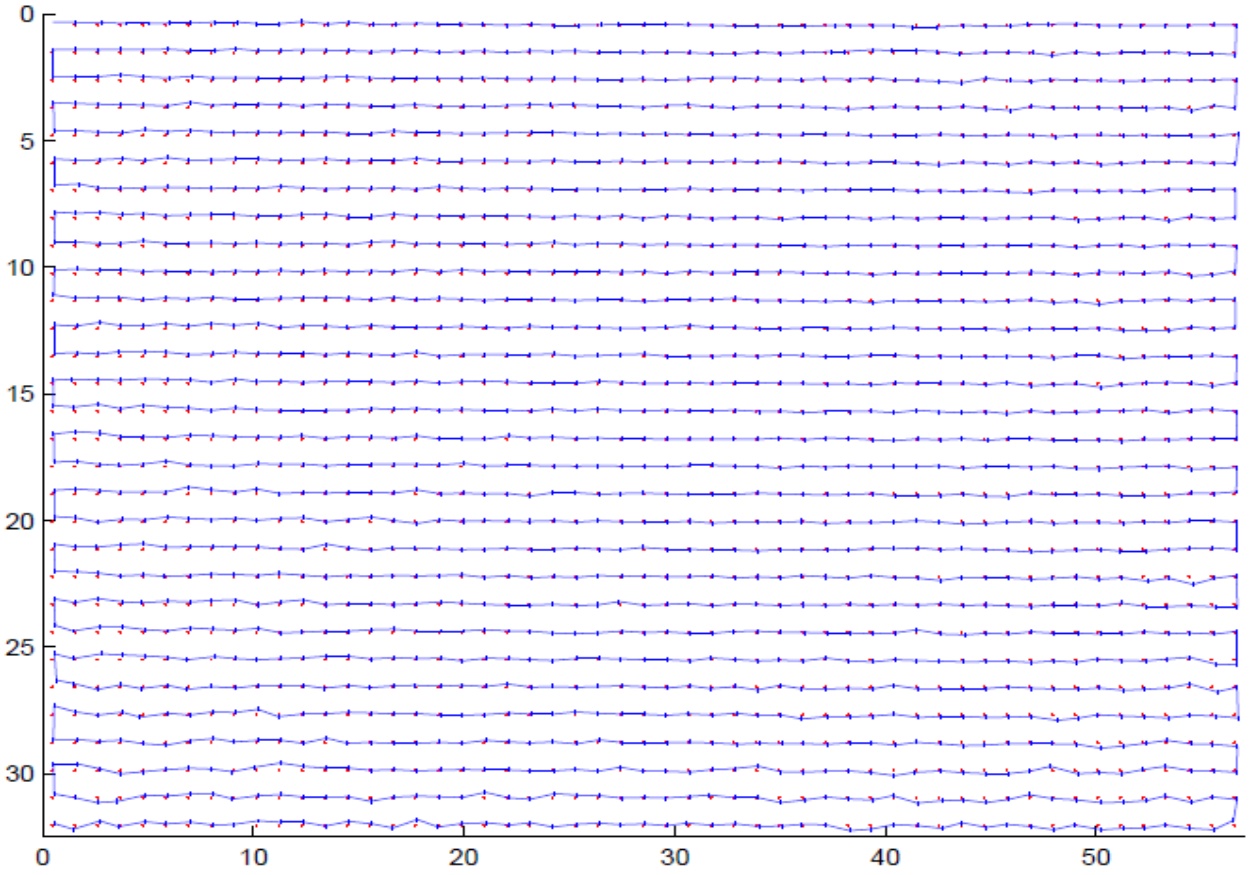


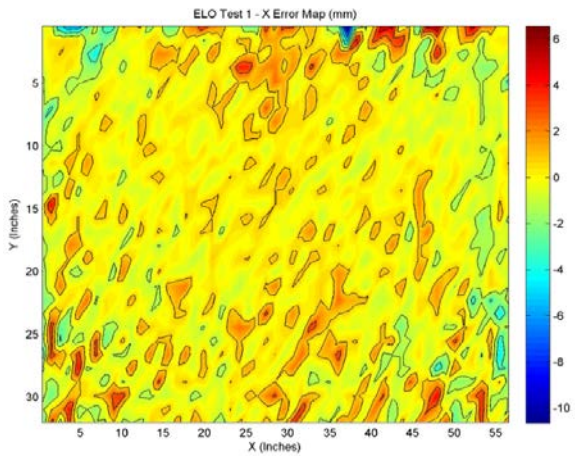


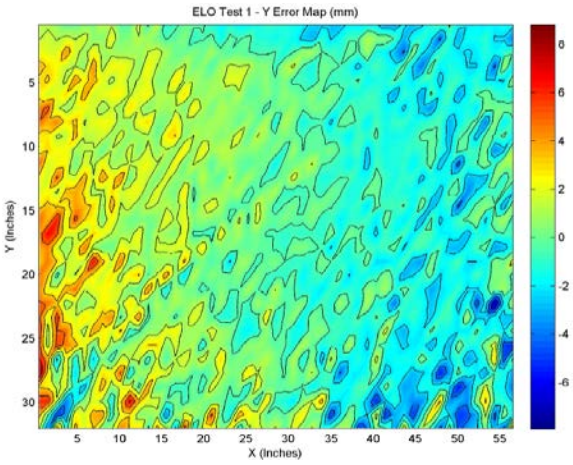


Trial-7 -- 55 LEDs De-rated:

Error at 90: 3.621mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.868mm
Mean X Error: 0.8506mm
Mean X Error without Nulls: 0.8506mm
Mean Y Error: 1.488mm
Mean Y Error without Nulls: 1.488mm

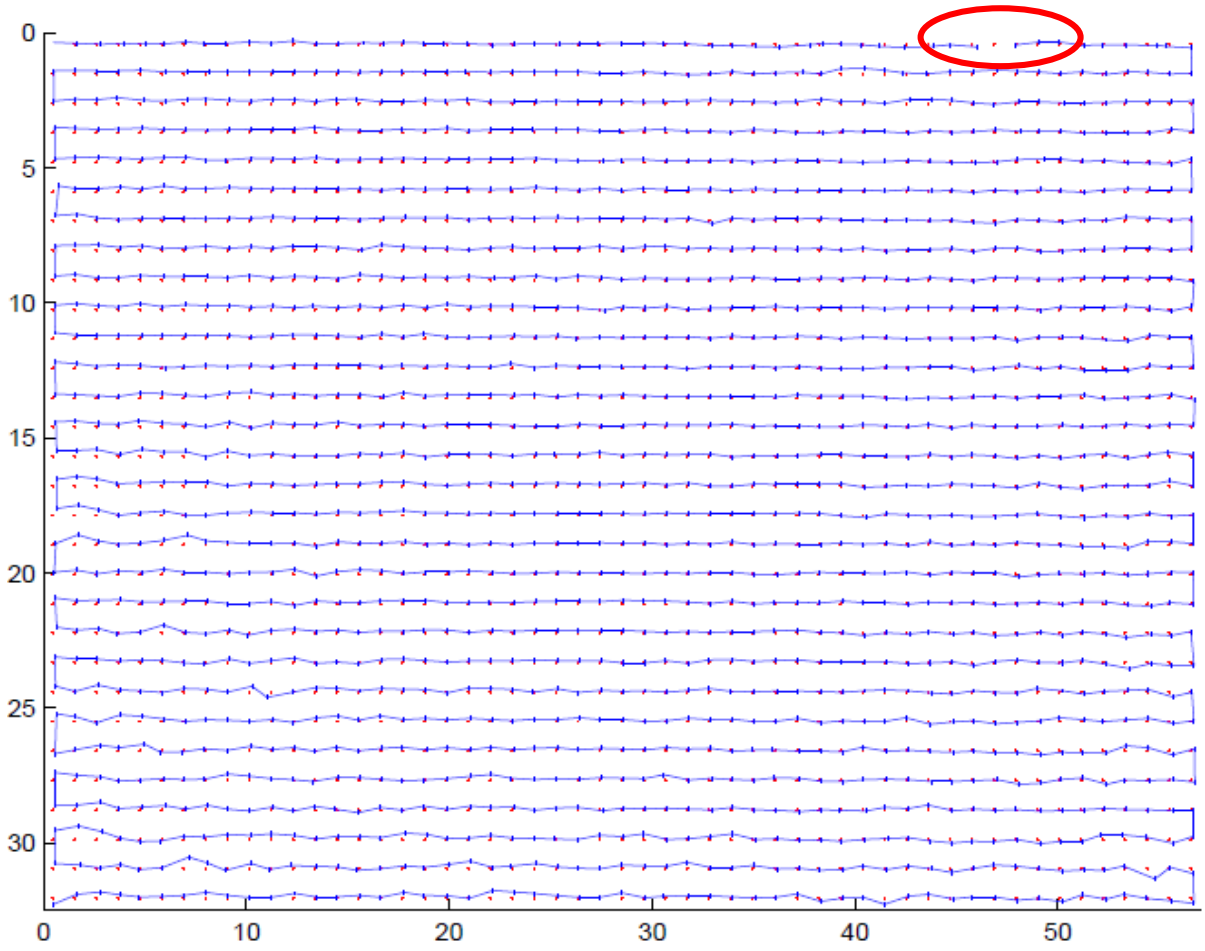


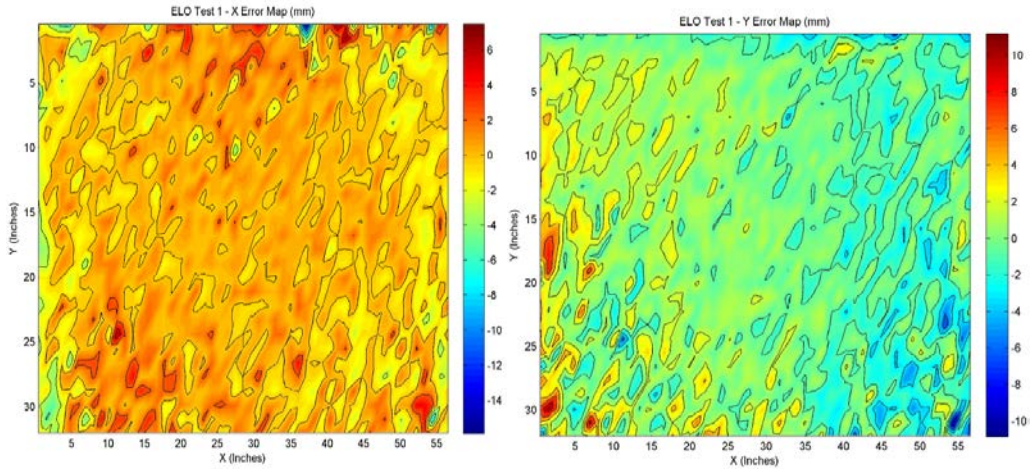




Trial-10 – 79 LEDs De-rated:

Error at 90: 3.822mm
Missed Data Points in x: 1
Missed Data Points in y: 1
Mean Total Error: 1.954mm
Mean X Error: 1.093mm
Mean X Error without Nulls: 1.09mm
Mean Y Error: 1.4mm
Mean Y Error without Nulls: 1.398mm





2.1 Method 1 – Results

Table 2 summarizes the results of all tests. It can be clearly seen that even when 79 LEDs were de-rated by over 95% the performance of the touch screen is barely affected.

Table 2: Trial results from the accuracy robot plots

Trial	De-rated LEDs (Total)	Mean X Error (mm)	Mean Y Error (mm)	Mean Total Error (mm)
1 - Baseline	**0**	1.474	.5965	1.676
2	**9**	1.145	.7657	1.499
3	**18**	.8155	.7337	1.217
4	**27**	.9038	1.202	1.652
5	**39**	.7739	1.283	1.655
6	**45**	.8238	1.51	1.882
7	**55**	.8506	1.488	1.868
8	**63**	.9848	1.614	2.079
9	**71**	1.031	1.234	1.775
10	**79**	1.093	1.4	1.954

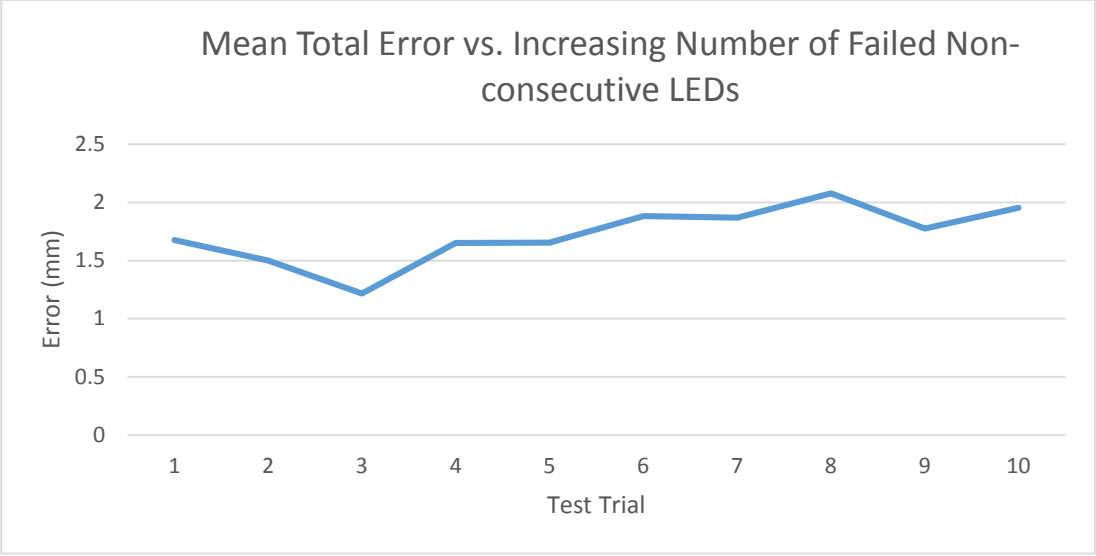


Figure 6: Graph of relationship between Mean Total Error and number of failed non-consecutive LEDs

3.0 Method 2 – Consecutive LEDs De-Rated

The second sets of tests were conducted to evaluate the performance degradation when consecutive LEDs were de-rated. Again, multiple tests were conducted by de-rating 3 additional LEDs each time.

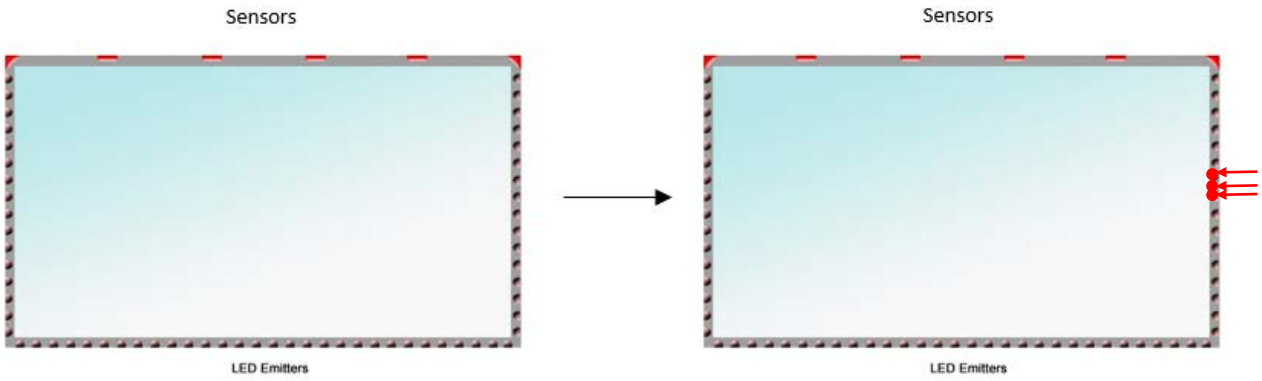
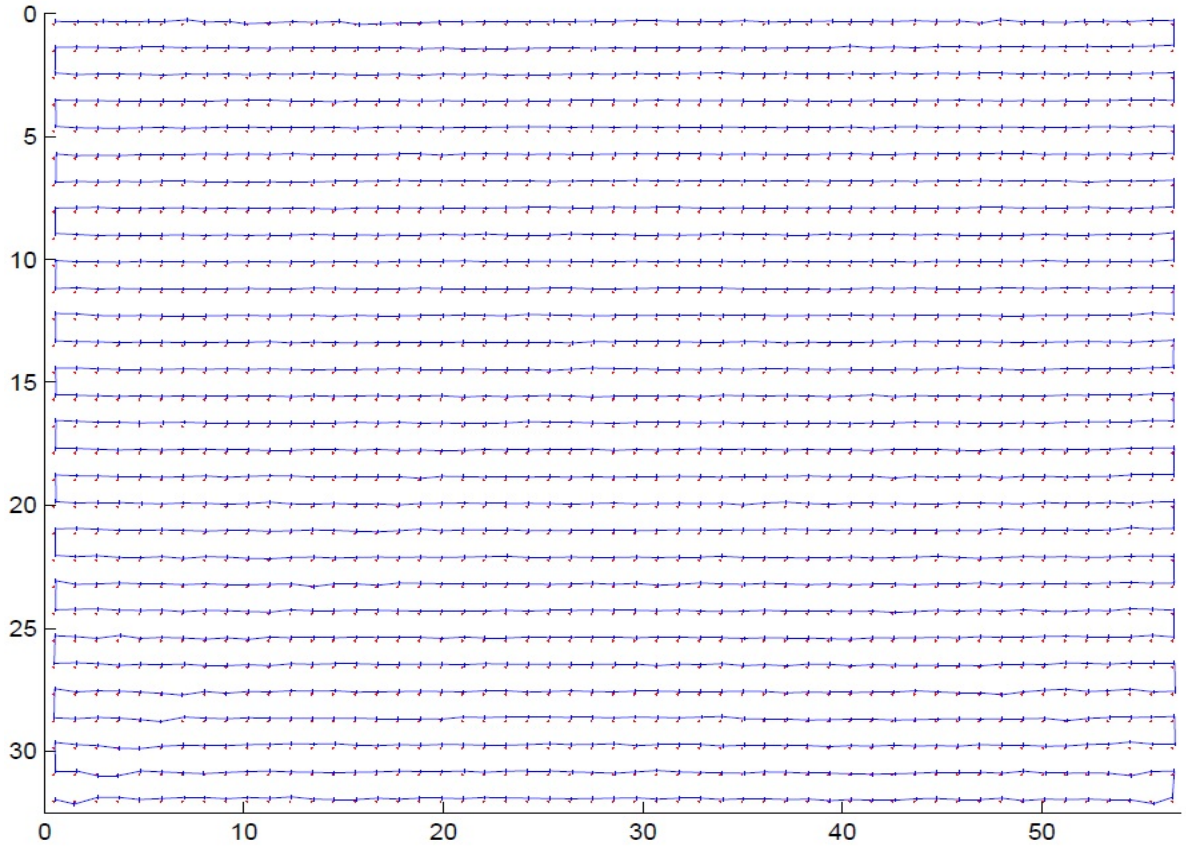


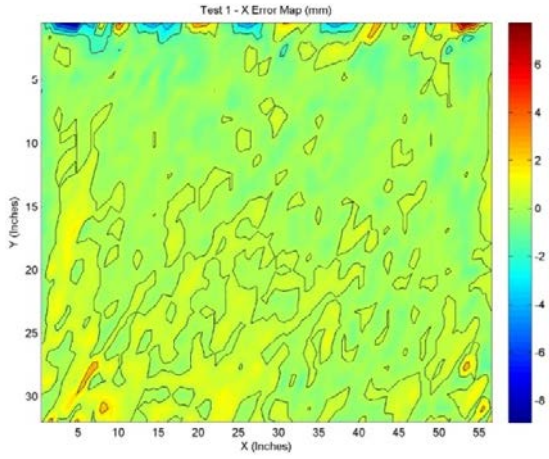
Figure 7: Removing consecutive IR LEDs from the light bars each test. (Red arrow and dot represent failed LED)

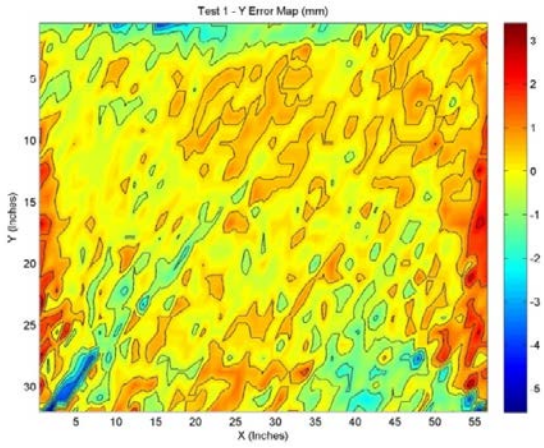
The following set of trials show a sub-set of results that were taken during the tests. Certain test results have been omitted because they did not show any significant deviation from the norm and also for the sake of brevity.

Trial-1 -- Baseline Test: 0 LEDs De-rated:

Error at 90: 1.599mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.8815mm
Mean X Error: 0.5194mm
Mean X Error without Nulls: 0.5194mm
Mean Y Error: 0.599mm
Mean Y Error without Nulls: 0.599mm

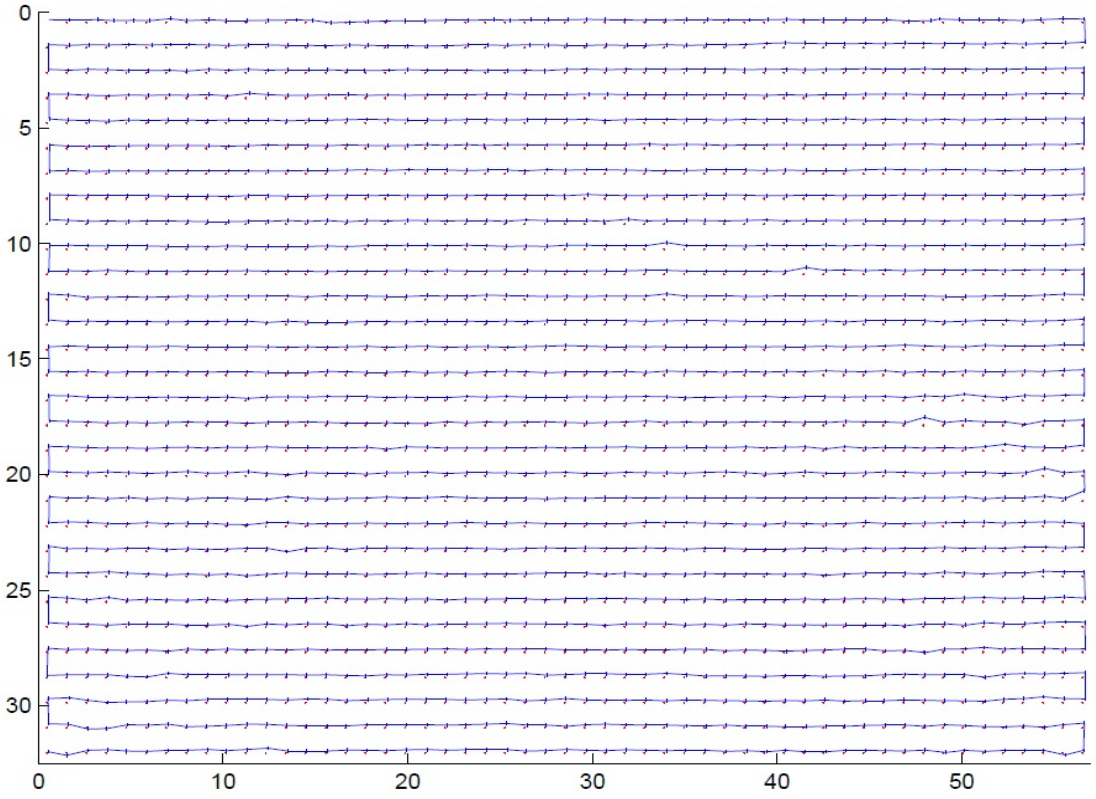


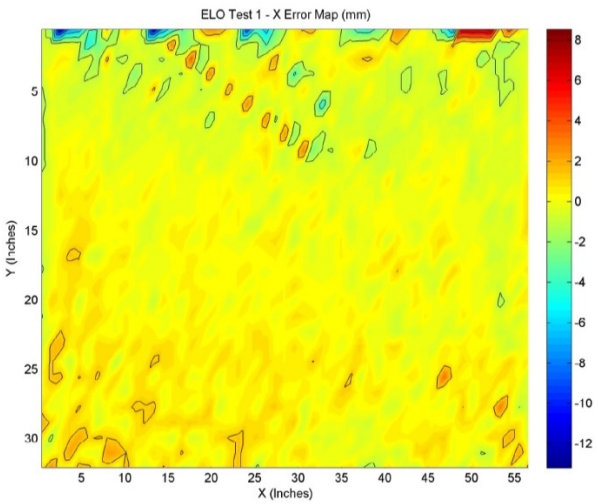


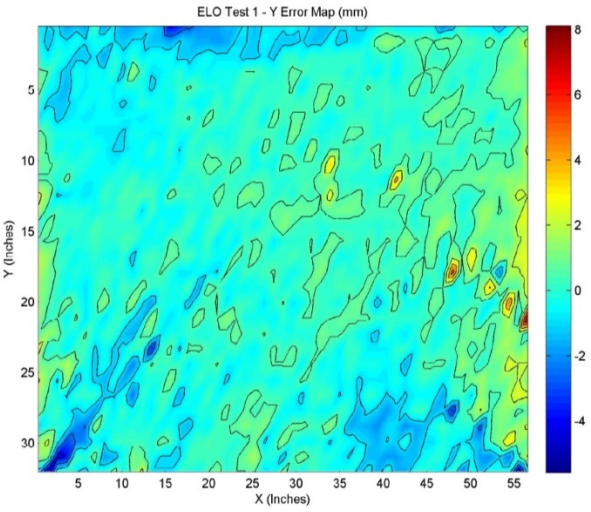


Trial-4 -- 3 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.798mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.012mm
Mean X Error: 0.6171mm
Mean X Error without Nulls: 0.6171mm
Mean Y Error: 0.6529mm
Mean Y Error without Nulls: 0.6529mm

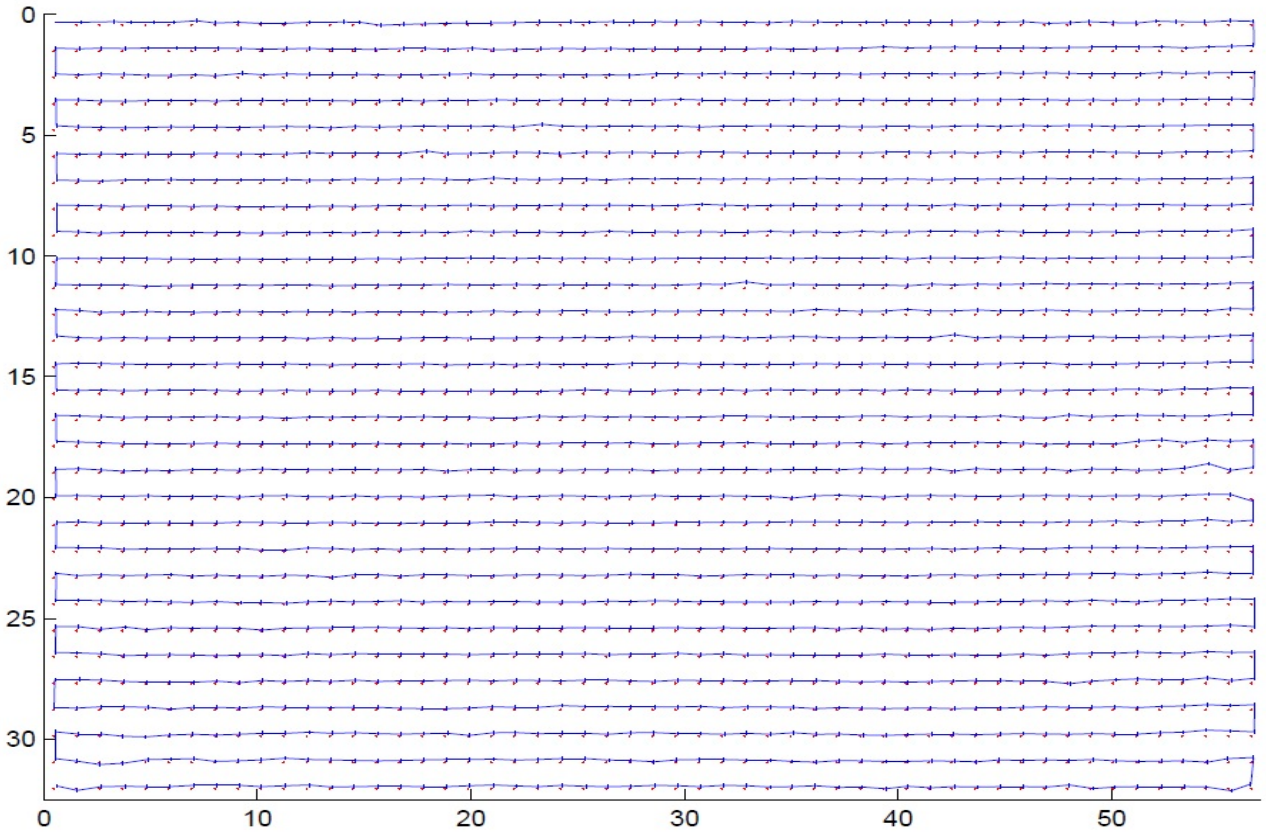


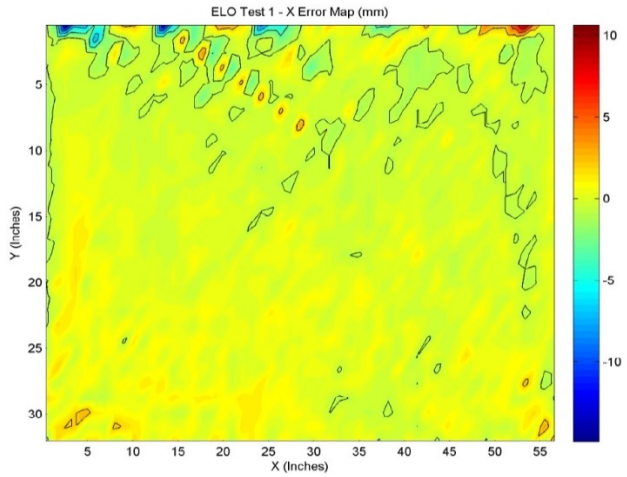


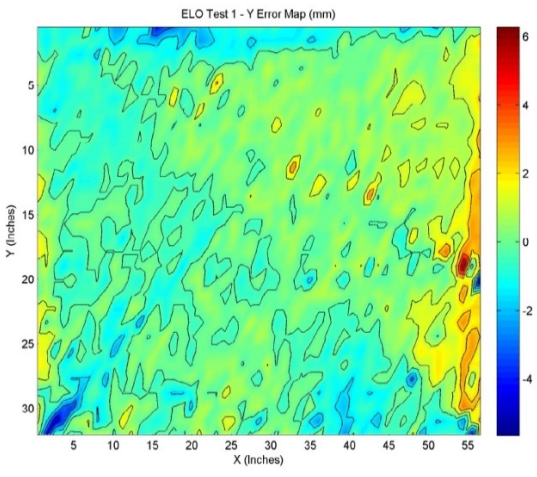


Trial-5 -- 6 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.935mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.04mm
Mean X Error: 0.6013mm
Mean X Error without Nulls: 0.6013mm
Mean Y Error: 0.7022mm
Mean Y Error without Nulls: 0.7022mm

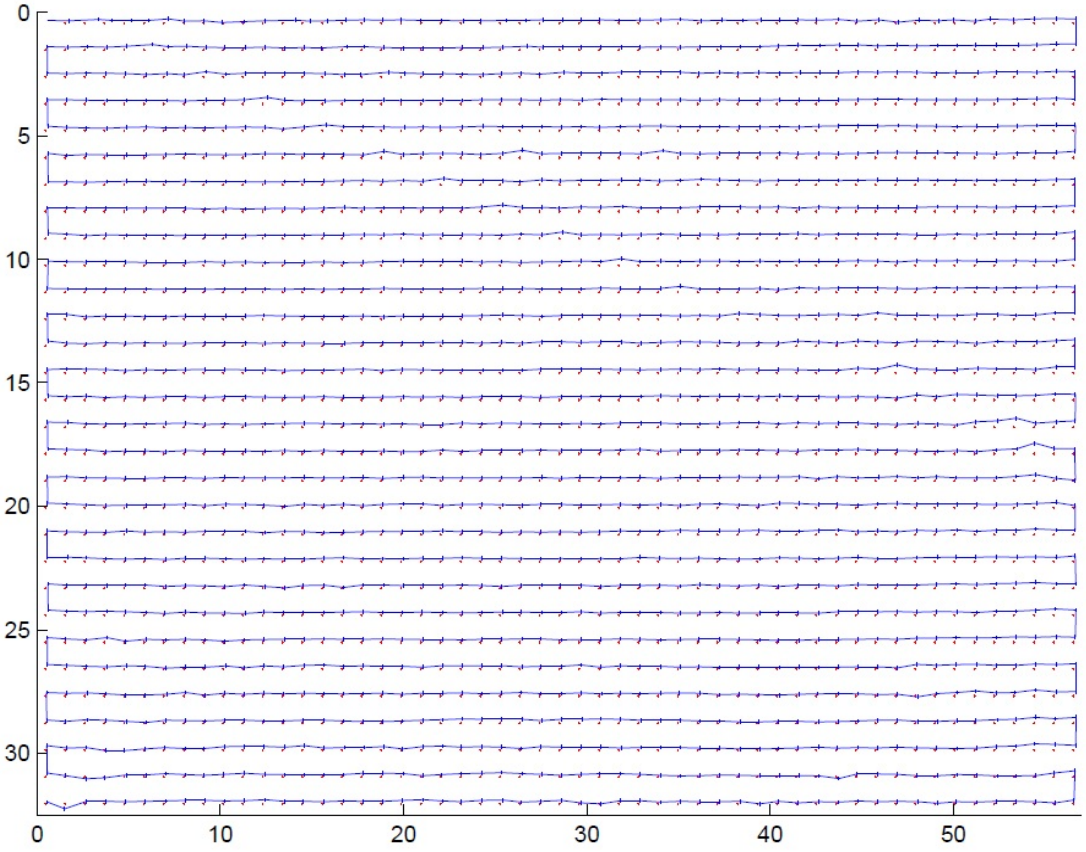


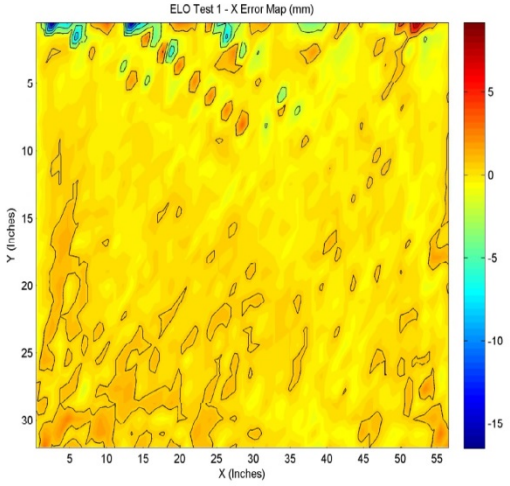


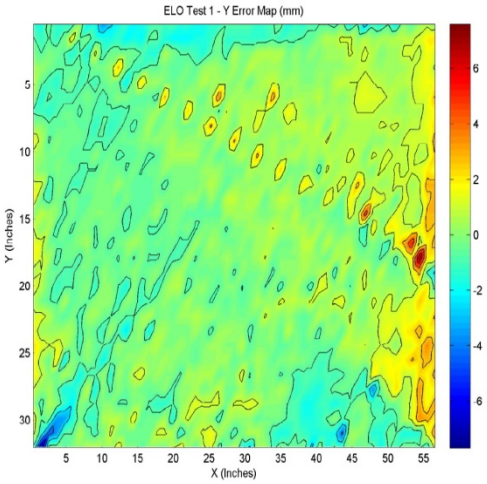


Trial-6 -- 9 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.961mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.059mm
Mean X Error: 0.5868mm
Mean X Error without Nulls: 0.5868mm
Mean Y Error: 0.7352mm
Mean Y Error without Nulls: 0.7352mm

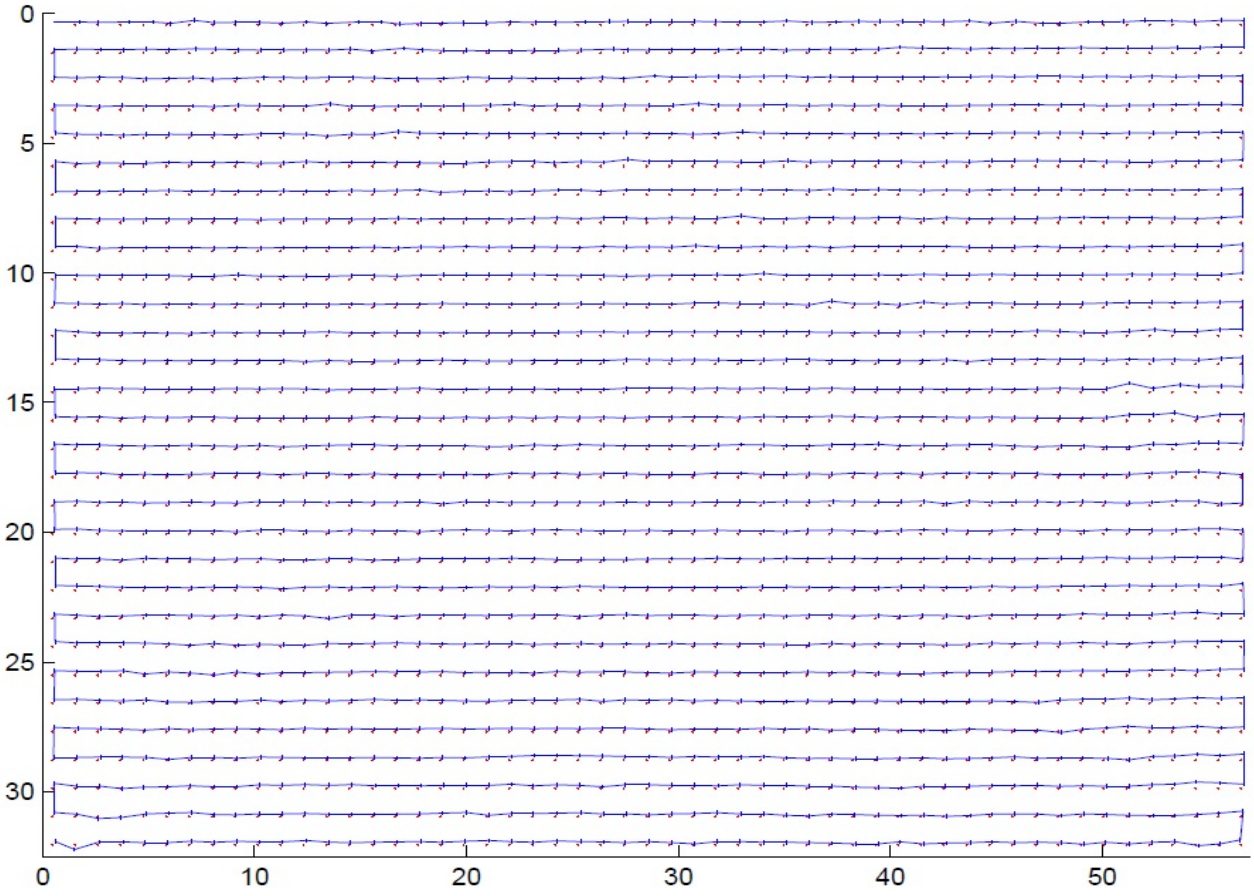


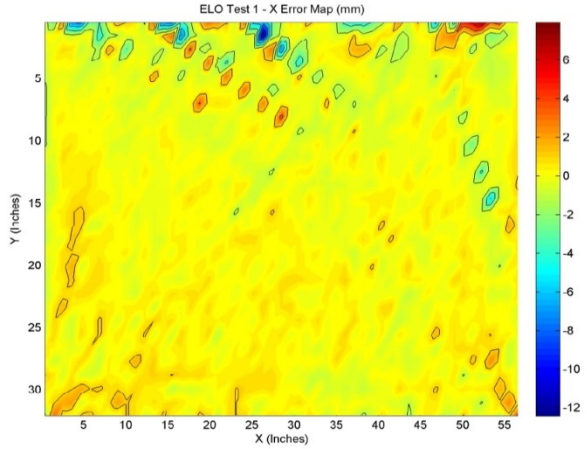


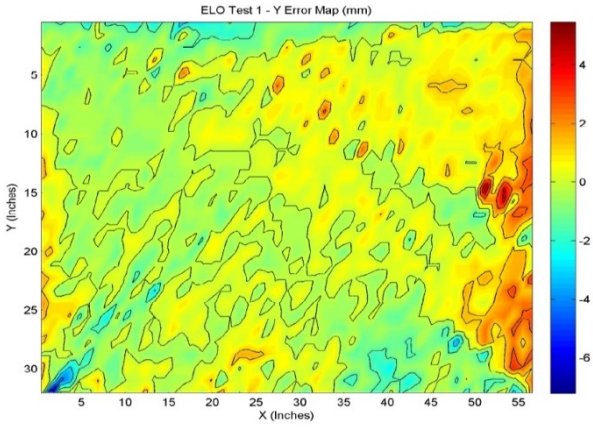


Trial-7 -- 12 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.885mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.014mm
Mean X Error: 0.5803mm
Mean X Error without Nulls: 0.5803mm
Mean Y Error: 0.6928mm
Mean Y Error without Nulls: 0.6928mm

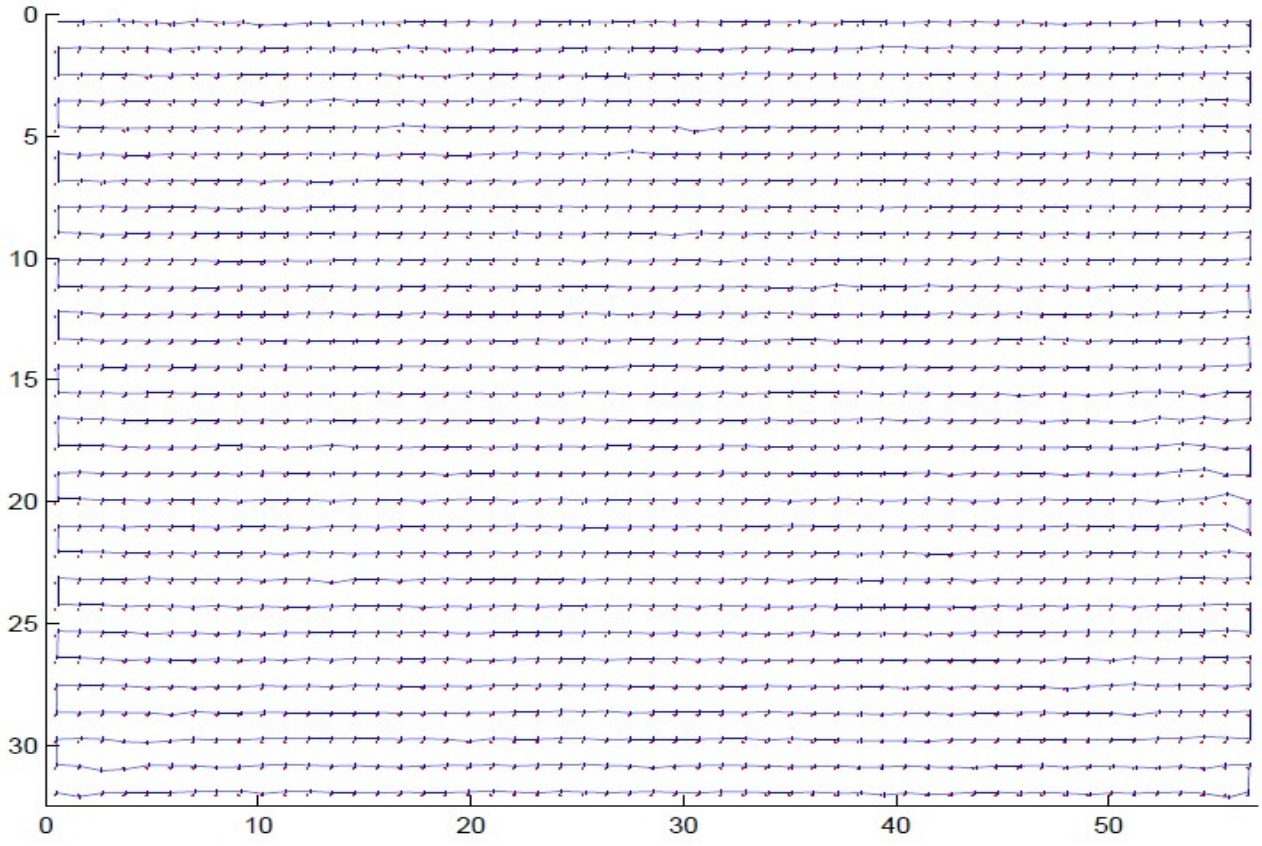


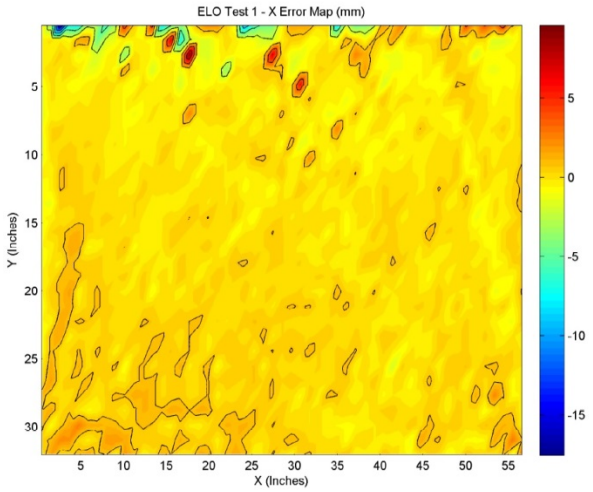


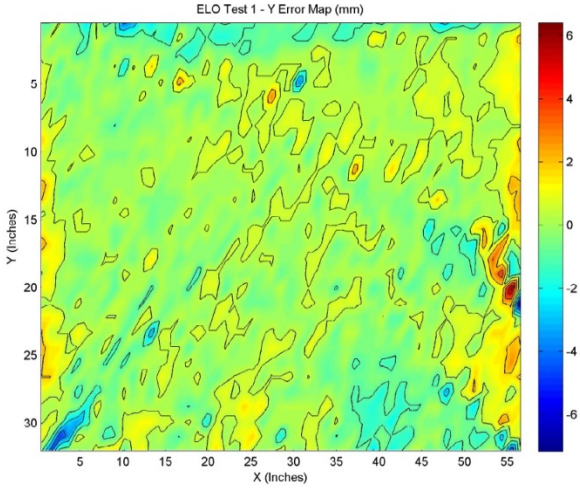


Trial-8 -- 15 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.715mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.9433mm
Mean X Error: 0.5796mm
Mean X Error without Nulls: 0.5796mm
Mean Y Error: 0.6045mm
Mean Y Error without Nulls: 0.6045mm

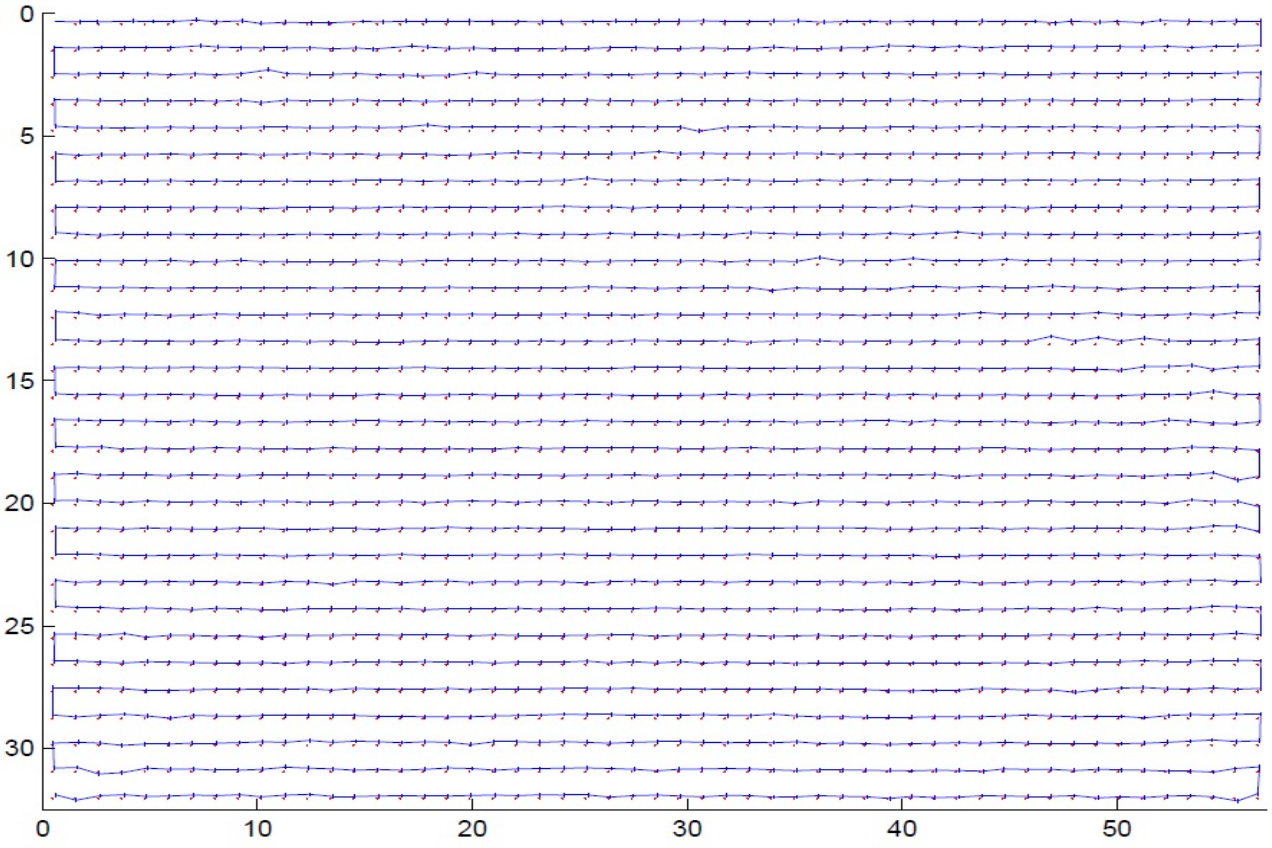


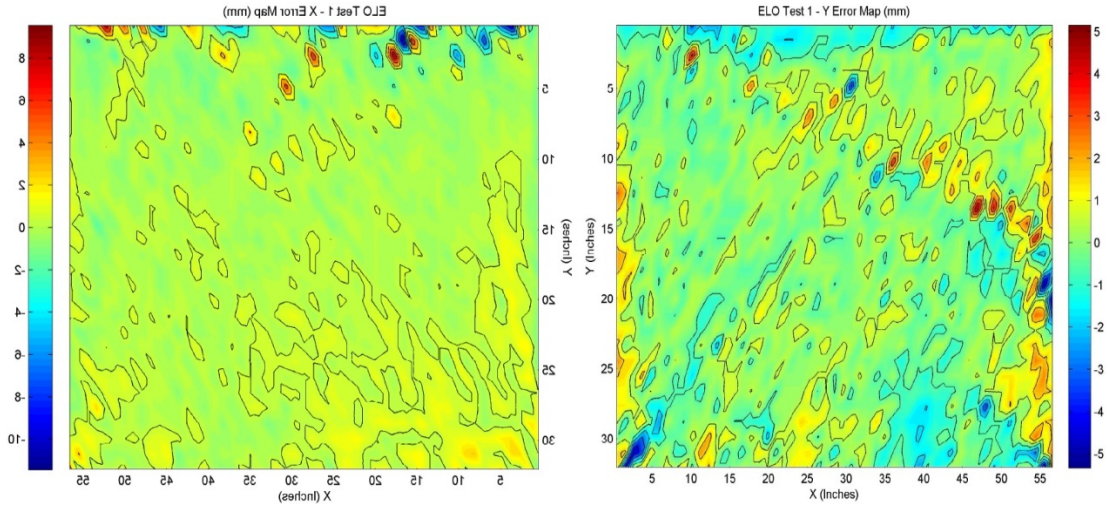




Trial-9 -- 18 consecutive LEDs De-rated from the middle of left light bar:

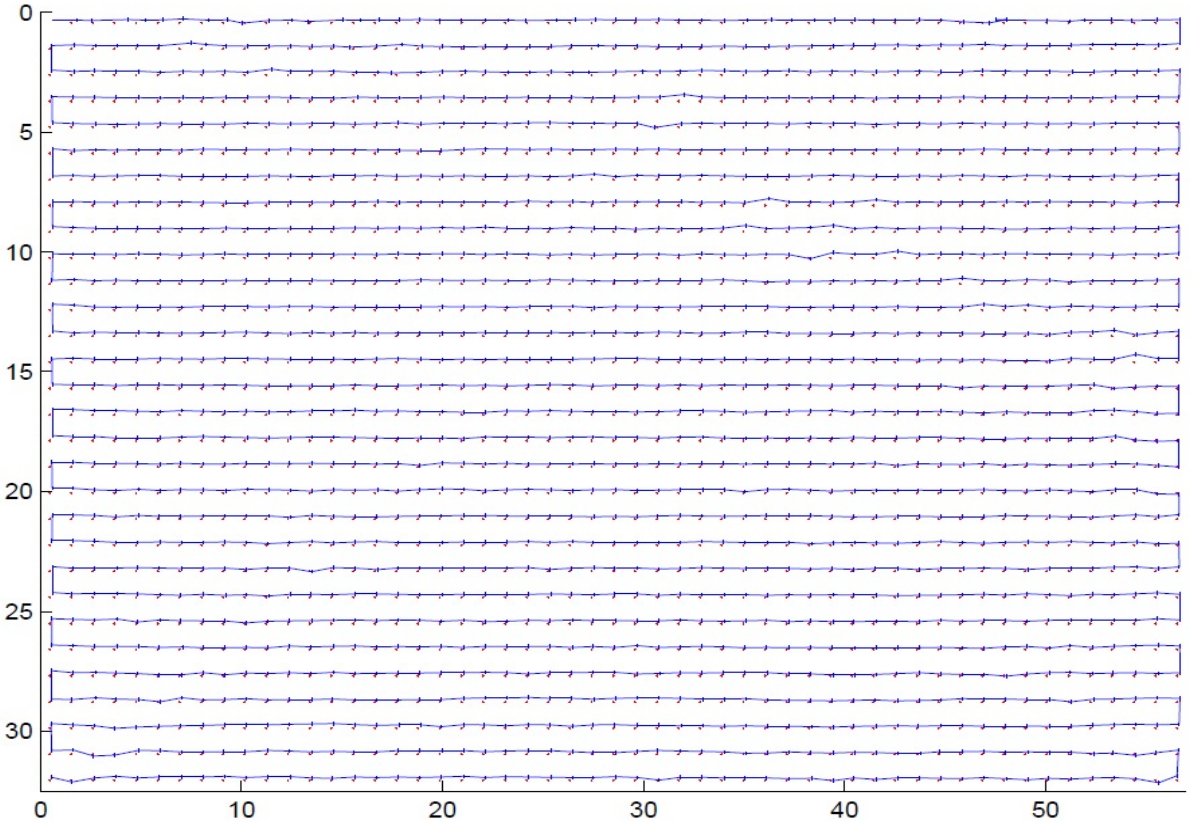
Error at 90: 1.771mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.9781mm
Mean X Error: 0.5938mm
Mean X Error without Nulls: 0.5938mm
Mean Y Error: 0.6334mm
Mean Y Error without Nulls: 0.6334mm

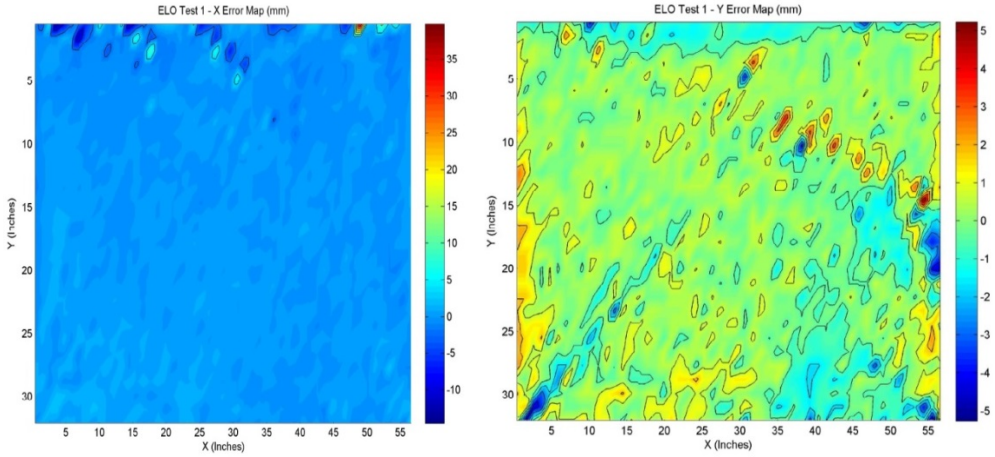




Trial-10 -- 21 consecutive LEDs De-rated from the middle of left light bar:

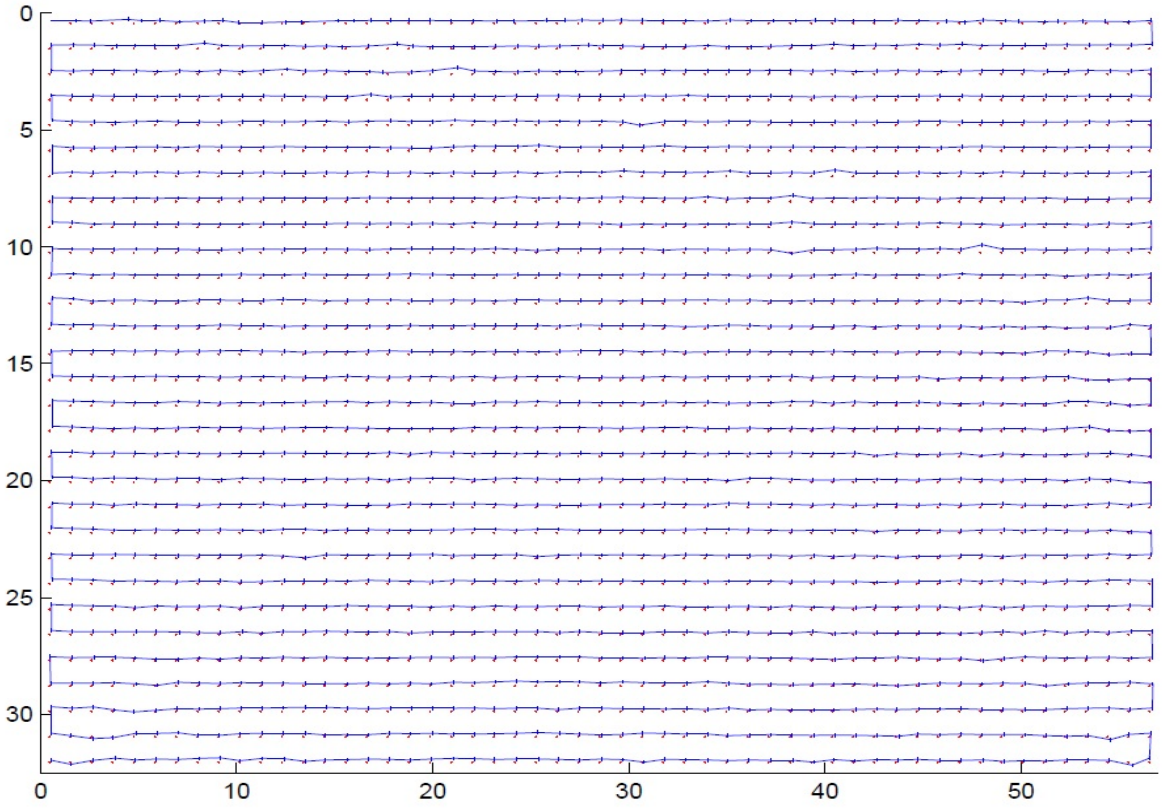
Error at 90: 1.735mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.9987mm
Mean X Error: 0.6165mm
Mean X Error without Nulls: 0.6165mm
Mean Y Error: 0.6287mm
Mean Y Error without Nulls: 0.6287mm

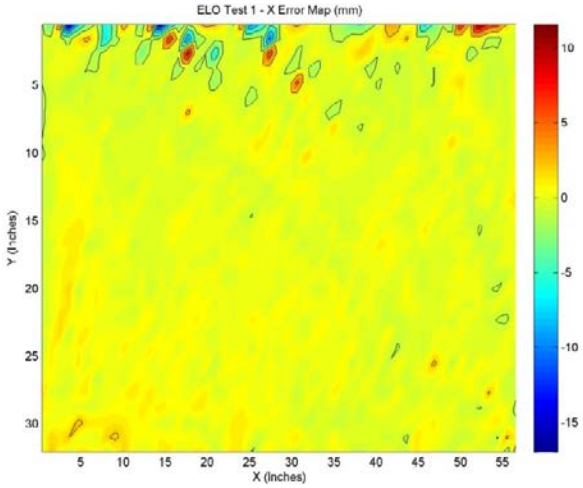


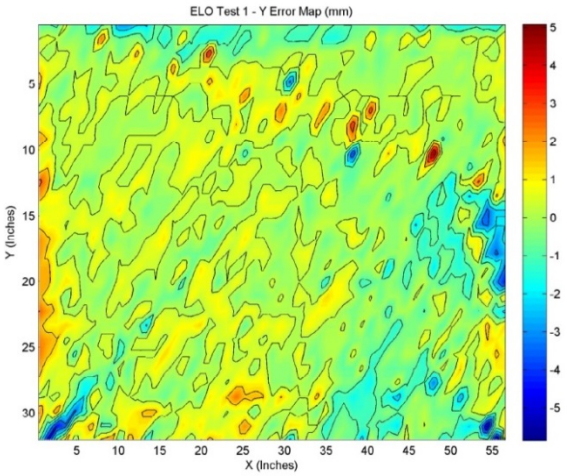


Trial-11 -- 24 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.813mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.9888mm
Mean X Error: 0.5991mm
Mean X Error without Nulls: 0.5991mm
Mean Y Error: 0.6311mm
Mean Y Error without Nulls: 0.6311mm

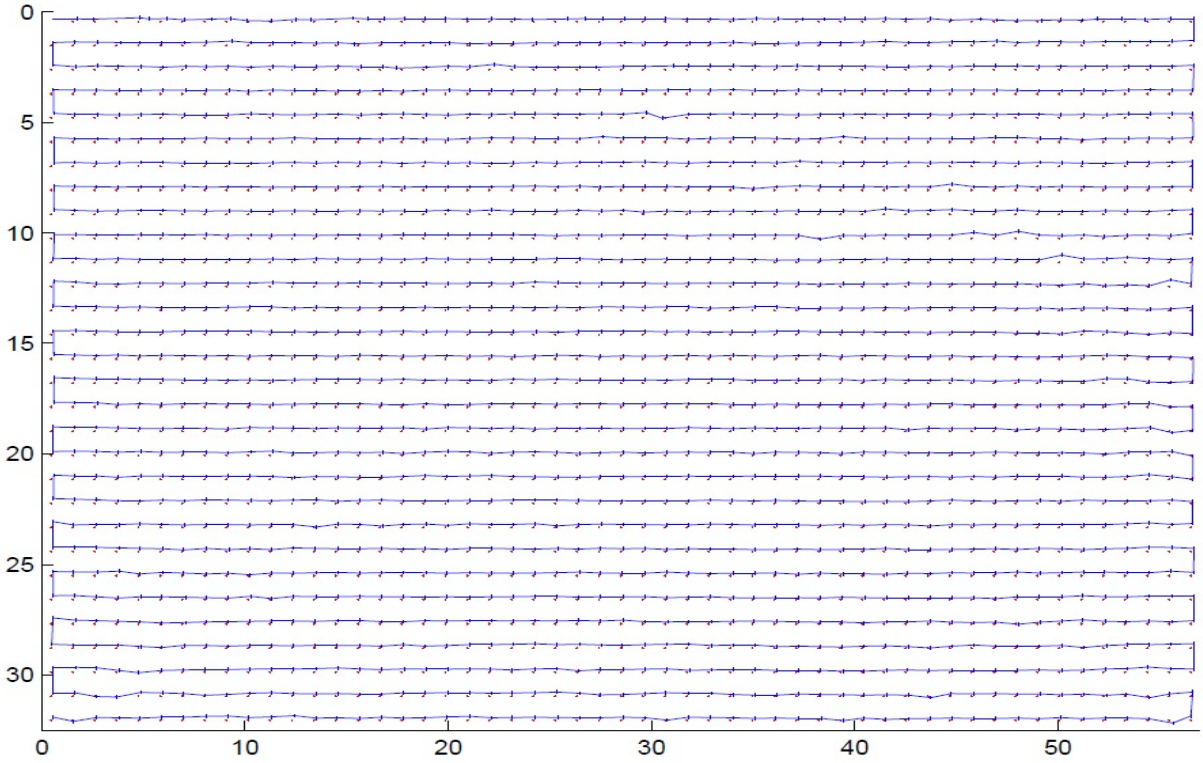


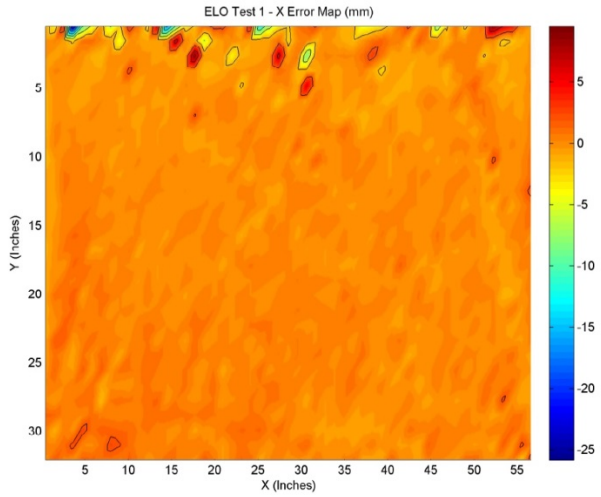


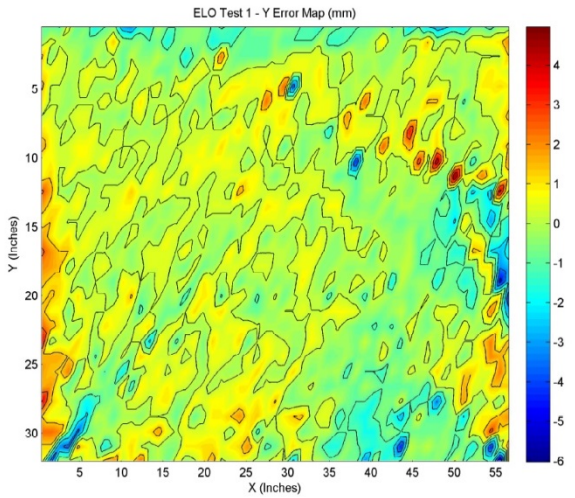


Trial-12 -- 27 consecutive LEDs De-rated from the middle of left light bar:

Error at 90: 1.825mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.014mm
Mean X Error: 0.6063mm
Mean X Error without Nulls: 0.6063mm
Mean Y Error: 0.6545mm
Mean Y Error without Nulls: 0.6545mm







3.1 Method 2 – Results

In this test, up to 27 consecutive LED's were De-rated and not even a single touch point was missed by the robot accuracy testing machine as can be seen in the 12th trial. The brightness value graphs (*Figure 3 and 4*) are shown to illustrate the values at the time of baseline testing (0 LEDs De-rated) and also to show the low level of 27 De-rated consecutive LEDs.

Table 3: Trial results from the accuracy robot plots

Trial	De-rated LEDs (Total)	Mean X Error (mm)	Mean Y Error (mm)	Mean Total Error (mm)
1 - Baseline	**0**	.5194	.599	.8815
2	**1**	.5131	.5844	.8668
3	**2**	.5418	.6065	.9119
4	**3**	.6171	.6529	1.012
5	**6**	.6013	.7022	1.04
6	**9**	.5868	.7352	1.059
7	**12**	.5803	.6928	1.014
8	**15**	.5796	.6045	.9433
9	**18**	.5938	.6334	.9781
10	**21**	.6165	.6287	.9987
11	**24**	.5991	.6311	.9888
12	**27**	.6063	.6545	1.014

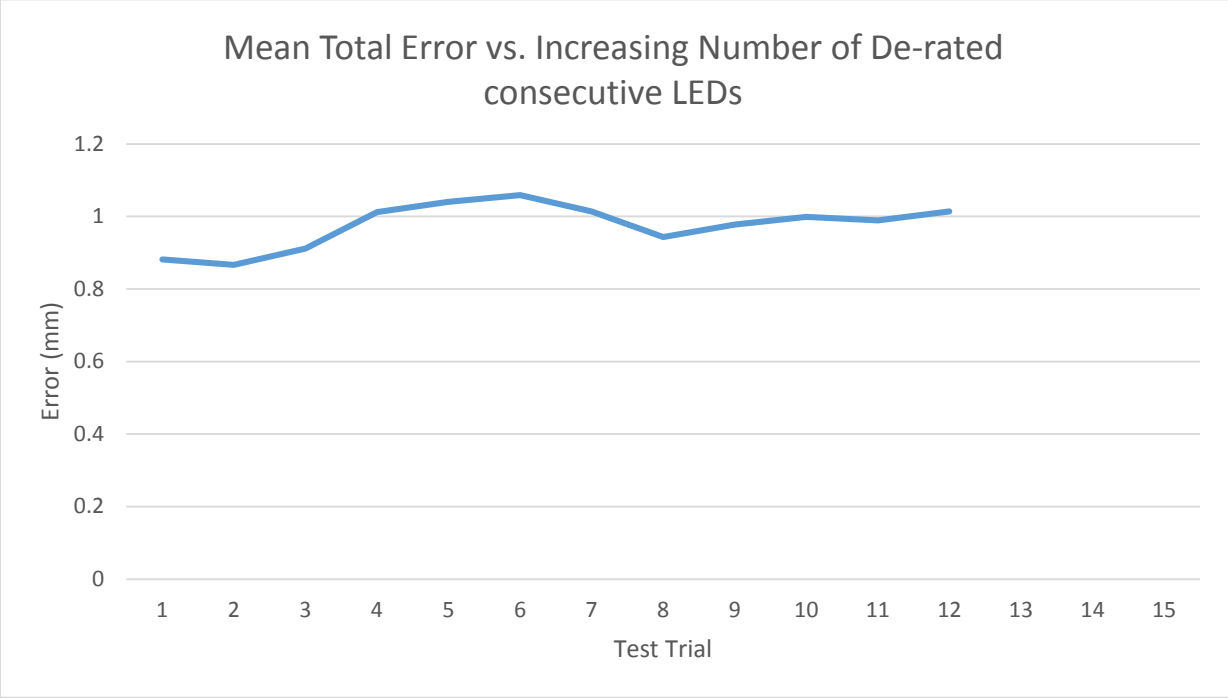


Figure 8: Graph of relationship between Mean Total Error and number of De-rated consecutive LEDs

4.0 Conclusion

The Baanto ShadowSense touch frame has a very redundant and robust design. The design allows for a large number of LEDs in the frame to degrade before there is any degradation in the performance of the system. The effect of both consecutive de-rated LEDs and non-consecutive de-rated LEDs were investigated with respect to touch performance and accuracy. As shown above approximately 26% non-consecutive LEDs are able to fail with minimal variation in performance. The second portion of the testing showed that approximately 9% or 27 consecutive LEDs were able to fail before any change in performance could be seen.