Increasing Profitability through Process Optimization: Better Than Outsourcing

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Introduction

Research has shown that U.S. companies can realize higher profits over outsourcing by putting their houses in order and fine-tuning their production processes, with automation being a key contributing factor. Machine capability analysis, or performance verification, is the first step to ascertaining that all of the automated equipment in the line, from printers to pick and place to reflow systems, are performing to specification.

This paper examines techniques and methodology used in Machine Capability Analysis (MCA) and equipment performance verification, using hardware and software quality tools, to analyze machine capability, checking the basic settings and functions of the equipment to identify, control, and correct failures, so that the unit(s) can once again assemble product within the original quality specifications established by its manufacturer.

The data and measurement results obtained provide the base for stable and controlled processing. Statistical specification-based results help validate accuracy and repeatability performance, which allows users to improve product quality and optimize performance for increased manufacturing profitability.

Outsourcing: the Best Deal?

Outsourcing electronics manufacturing to the Far East continues unabated. Large, high-volume manufacturers of electronics, particularly popular consumer products, will continue to seek out low labor cost avenues of manufacture in order to realize the highest possible margins. We have seen China take the lion's share of outsourcing for some years now; prior to that, the center was Mexico. Now, as the standard of living rises in China and labor costs rise, large multinational corporations will, and are, once again seeking lower-cost manufacturing environments. To this extent, Vietnam has begun adding infrastructure to support foreign investment in electronics assembly, and plants are already going online. India is another venue; North Africa may be next.

One of the key forces driving this trend is the huge market in developing countries for the same consumer electronics popular in first-world countries. These are primarily inexpensive computers (notebooks, laptops), game consoles, and especially wireless communication devices, i.e., multifunction cell phones, and graphic display items such as televisions and monitors. At the same time, advancing technology and competition are driving down the cost of these products to the end user. Where the cost of products to the consumer is low, so are the margins for the manufacturer, who ultimately has little choice but to seek cheaper labor markets to manufacture these products.

Not surprisingly, however, during the past couple of years, although a significant amount of business is still outsourced, a lot of work has begun coming home. Small and mid-sized companies are discovering that outsourcing their electronics assembly to the other side of the world is fraught with logistical and quality control issues that erode profitability. As margins shrink, the argument for outsourcing becomes untenable.

Increasingly, Tier 2 U.S. electronics manufacturers are learning that when it comes to profitability and quality, it's much easier to control these factors at home rather than in a factory on the other side of the world. Indeed, the entire range of manufacturers - from the smallest to the largest – can do better right here if they optimize their manufacturing processes. This will become increasingly so as electronics assembly enters the "modern era", post-RoHS and WEEE, the imminent future when process control and quality focus will be key issues in soldering and circuits manufacturing.

Outsourcing to shifting cheap labor markets means sending increasingly complex and difficult-to-manufacture circuit assemblies halfway around the world to be built using unknown equipment by unseen companies and faceless personnel. Shipping costs, time, and potential damage, quality issues, loss of control, and other factors quickly reduce or eliminate any low-cost labor profit gain. Product that returns defective must be reworked, or if unusable, scrapped. Rework is quite possibly the biggest profit-eater in the entire assembly process.

There is a better way. Optimizing the manufacturing process here at home, where knowledge, advanced technology, and process/quality control are within arm's length, is the way to higher profitability and fewer headaches.

In a study titled "Production Migration: Do the Numbers Add Up?" by Bjorn Dahle and Ronald Lasky, published in early 2003, the authors demonstrate how U.S. companies can realize higher profits over outsourcing by putting their houses in order and fine-tuning their production processes. This comparison was made really in 2002, before the challenges of lead-free assembly had truly hit home. The authors cite automation as a key factor, because automation means higher productivity at lower cost per unit by eliminating labor costs, as well as the uncontrollable variables introduced by human involvement in the manufacturing process. The authors refer to the "stunning effect that productivity has on profitability" and summarize that "it is cheaper and more profitable to improve at home than to send production overseas."

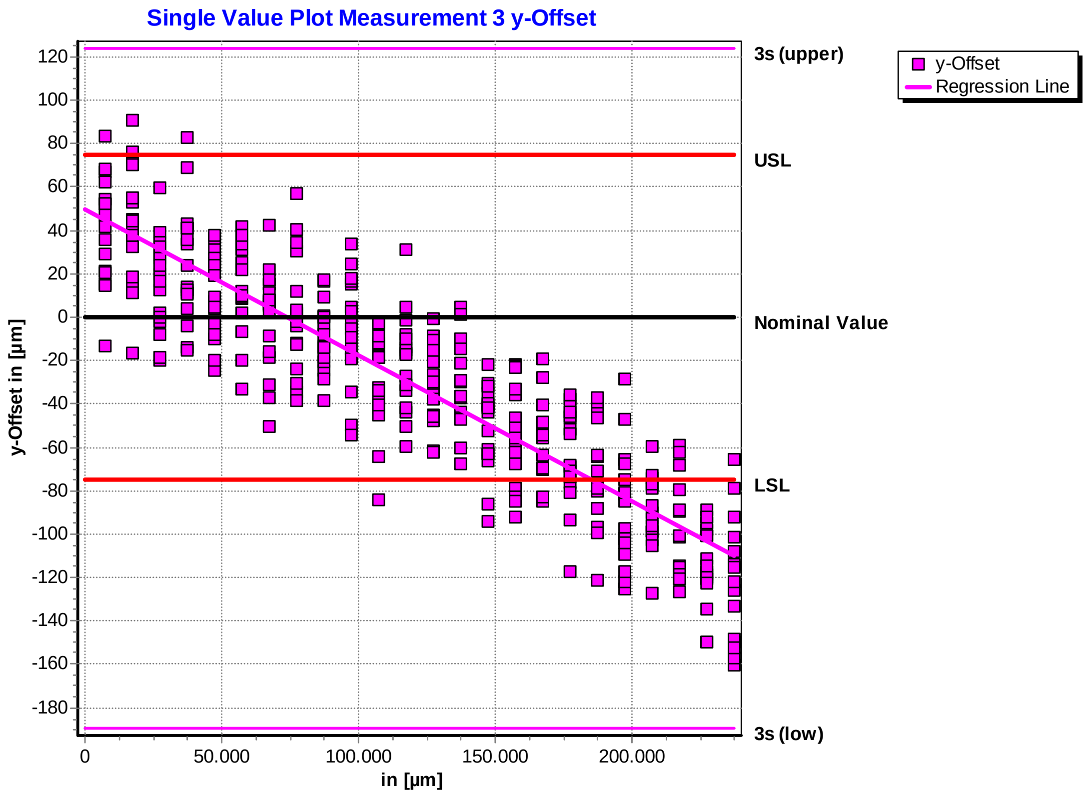


Figure 1 - Single values *y* depending on *x* position displaying severe table rotation.

Improving the process at home is not a simple task. If we want to increase the percentage of automation in the process, which means greater reliance on sophisticated equipment, then we must also ensure that such equipment is performing flawlessly and to its manufacturer's specification, without errors or offsets that cause defects, down time, and do little to widen the already narrow process window imposed by lead-free assembly. Machine capability analysis, or performance verification, is the first step; this process ensures that all of the equipment in the line, from printers to pick and place to reflow systems, are all performing to spec. This is a prerequisite; all other process adjustments and fine-tuning must follow after, because if there is variability in machine performance, in accuracy or repeatability, for example, all other process refinements will be meaningless, as true repeatability cannot be maintained.

The cost of not verifying equipment performance and correcting errors will be the slow attrition of profits due to higher defect levels, more rework, lower overall yields, production stoppages, truly costly over time, and remember that such costs are cumulative.

This is more than theory. Already, large OEM's are using performance verification methodology to certify the high-performance capabilities of their equipment. This is especially important as tolerances shrink and processing speeds and volume demands rise. The list of both OEM's and EMS companies using these tools to fine-tune their production process equipment has expanded dramatically.

What is Machine Capability Analysis (MCA) Testing?

Machine Capability Analysis (MCA) testing is performed using a machine and testing technology developed by CeTaQ in Germany. The machine, the CmController uses special vision algorithms, highly accurate glass plates and components to provide independent measurement of Cp and Cpk indices on production equipment. All brands and models of SMT printers, dispensers, placement, feeders, reflow ovens, and other automated machines are validated; other equipment types include stencil manufacturing equipment, die bonders, laser labelers, photo-plotters, drilling machines, and more. Proprietary software operates the measurement equipment and provides statistical specification based results on machine quality performance. Comprehensive certification reports validate performance. The range of machines and processes that can benefit from performance verification or machine capability analysis (MCA) testing continues to widen. In the semiconductor packaging arena, it can be used to verify the accuracy of direct-write laser scribing and dicing systems; in printed circuit board fabrication, it finds application in verifying the accuracy of hole drilling and other fabrication processes. Performance verification ensures that production machines are operating to the original manufacturer's specifications. This is crucial to optimizing the manufacturing process to realize maximum yields, minimal defects, and repeatability, thus making domestic manufacturing a better deal than offshore outsourcing in many cases.

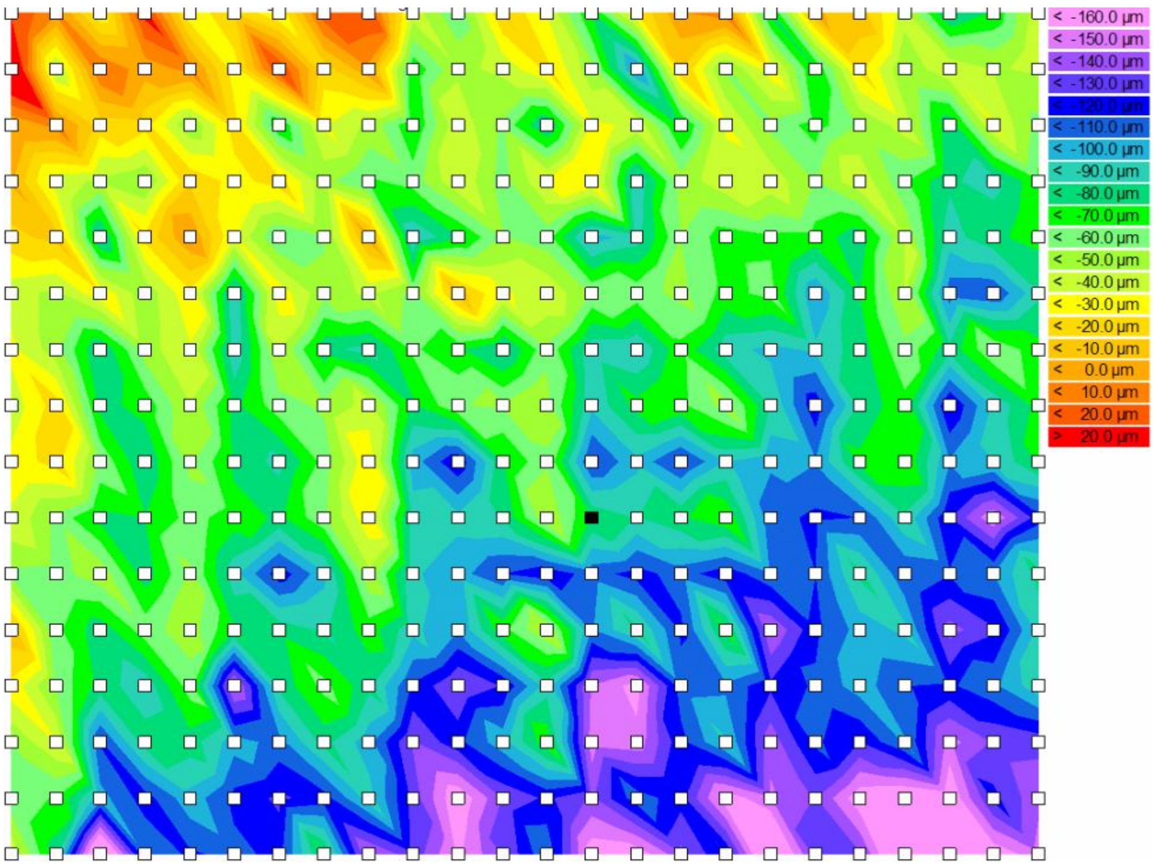


Figure 2 - Color accuracy map showing scaled placement deviations in *x*-direction.

Case Example: Uncovering Pick and Place Mechanical Issues

In one instance that is quite typical, Phoenix International, an EMS in Fargo, ND was having yield problems that the engineers knew had to do with the pick and place equipment, but could not pinpoint the cause. Some components weren't where they ought to be, or were skewed, or were missing, even though the machines had been programmed correctly for each product. This meant defects, and rework. A little bit of rework is expected, but this was too much, and the engineers began to suspect that it was due to more than just a little mechanical imprecision.

Phoenix International develops highly ruggedized electronic components and systems for industries that rely on their equipment to function under the most adverse conditions—industries such as on-highway, agriculture, heavy construction, industrial control, material handling and more.

The manufacturing environment is high-mix, low volume, with four SMT lines of primarily Panasonic (Panasert) equipment, and one CM module line. Due to the high-mix nature of the manufacturing, there's a lot of setup and changeover on the machines, leaving little time for deep-level process optimization. The products are primarily SMT assemblies, both board-level and final assembly are performed in the facility, plus product design from start to finish. To make matters more complicated, one production line is dedicated lead-free assembly.

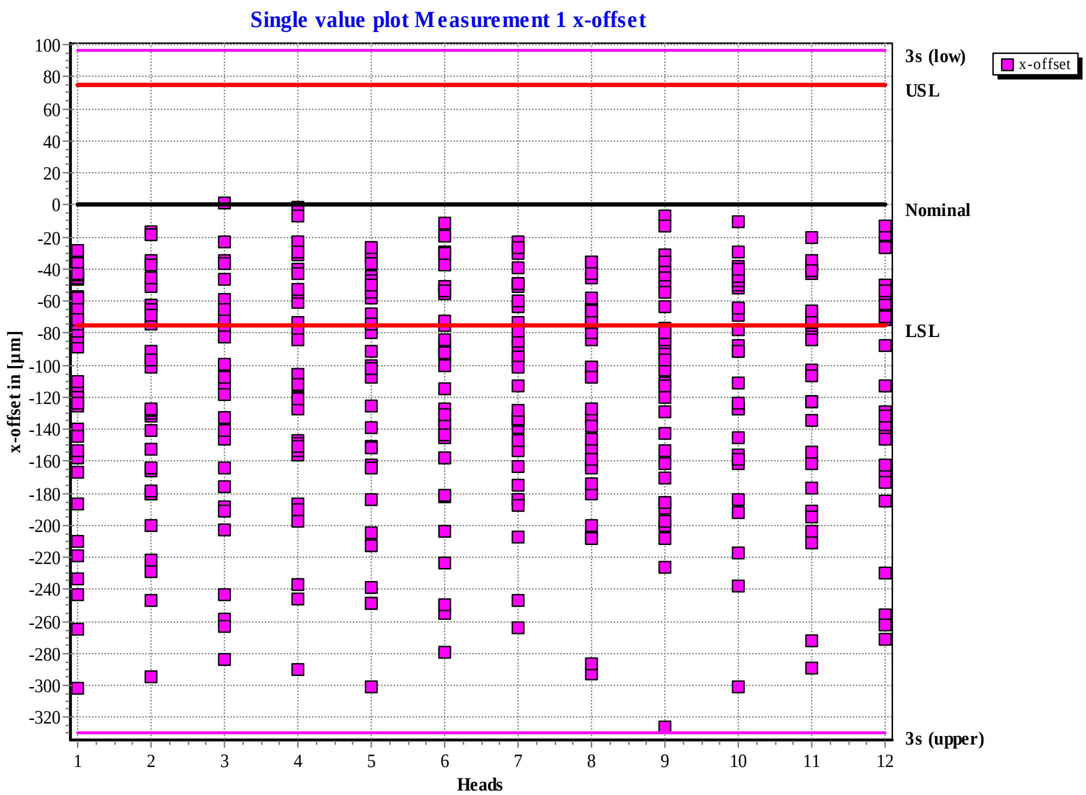


Figure 3 - Single value plot displaying significance of head variation and mean offsets in *x*-direction.

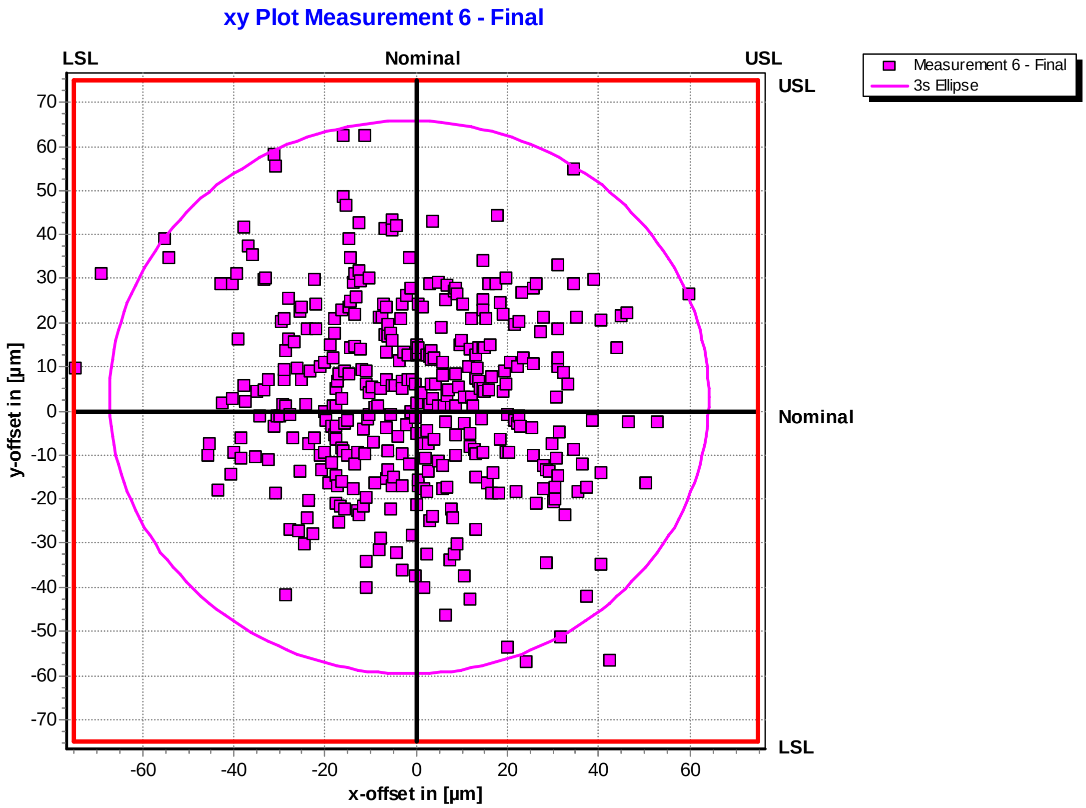


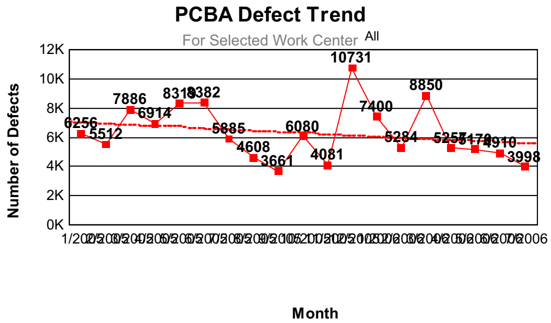
Figure 4 - *xy* Plot of final machine condition after calibration and adjustment.

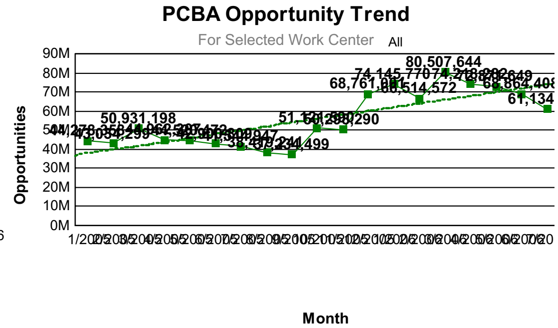
Problems with a rising rate of defect levels developed gradually. Emerging difficulties were primarily in the pick and place area, with a lot of off-pad issues that were related to nozzles, head calibration issues. There were a lot of missing component issues.

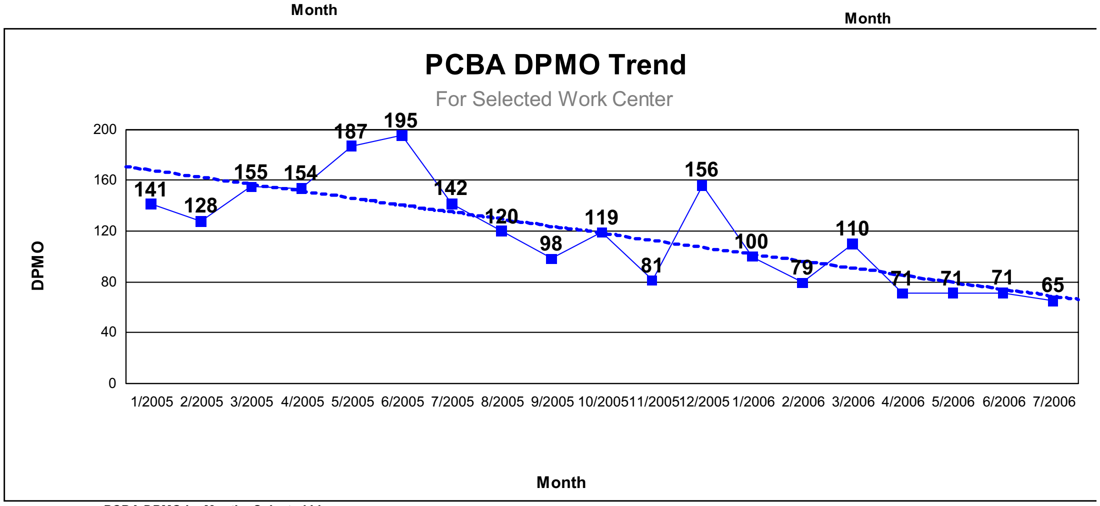
The most common problems found on chip shooter placement equipment, for example, are systematic offsets (80%). They can be offsets per head, per nozzle, per angle or simply a general offset. Offsets negatively affect chip shooter accuracy, resulting in PCB defects, lower yields, and rework. In MCA testing, technicians go into a manufacturer's facility and analyze placement machine capability, checking the basic settings and functions of the equipment (clamping, sensors, nozzles, camera, feeders, etc.) to identify, control, and correct failures, so that the machine can once again assemble product within the original quality specifications established by its manufacturer; see **Figures 1 through 4**.

During initial testing at Phoenix, all of the production machines were tested, and all failed to meet machine performance specifications. Ultimately the machines were analyzed, problems solved, and regularly-scheduled (annual) testing set up to keep the placement machines optimized. The customer, more importantly, learned how to analyze the data, to break down "machine performance" into different areas. For example, they may replace parts, such as movable rails, pillow blocks, grouped into an individual PM schedule for replacement even before the scheduled annual testing. Then, once the machine is tuned, it will perform flawlessly for the next twelve months. Testing, careful analysis of the results, and good PM scheduling are the formula required to keep the machines optimized.

The testing team generates the analysis and report, and the equipment manufacturer's service personnel implement the fix. During the initial testing at Phoenix, their engineers learned just how far out of control their process was. They actually had some placement nozzles in the wrong locations, and heads that were really way out in no-man's-land; but because they were not able to break it down to that level prior to the testing, they did not understand what their test data was indicating because the average was showing that they were fine. When they began breaking it down per head, they discovered that there were some placement heads that simply weren't functioning right, and required replacement. The list of mechanical issues was a long one, and new ones are uncovered whenever testing is performed. Correcting placement machine problems had a dramatic effect on defect levels and improved yields.



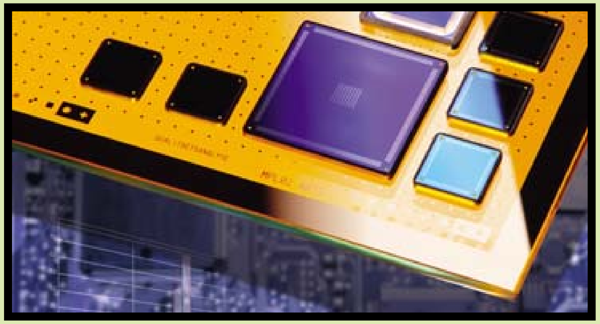




Report Title: *PCBA DPMO by Month - Selected Line*

Conclusion

A fine-tuned process is the best assurance of a high yield, low defect lean manufacturing capability that assures global competitiveness and individual profitability. Authors Dahle and Lasky maintain that automation is the key to higher productivity, and thus profitability over outsourcing. The benefits of automation, however, cannot be realized without a fine-tuned process free of the types of variables that impact repeatability.



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February 21, 2007

Presenting: Michael Sivigny

General Manager, CeTaQ Americas

Overview

- Outsourcing Trends
- MCA testing
- Performance Optimization
- Case Study Examples
- Summary

Outsourcing…

- Is it really necessary?
- In the 80’s it went to Japan
- To Mexico & East Europe in the 90’s
- At century turn it was off to China
- Early 2000’s economic downturn was the rush to get out of domestic mfg.
- Will it come full circle…

Outsourcing...

- Are we really saving against the China labor rate?
- Quality issues are significant, rework ruins profitability.
- Supply chain logistics make design changes difficult.
- Reliability products stay the course.
- Data supports domestic manufacturing should stay.

How to be better

- Focus on sound quality initiatives
- Train & implement 6 Sigma methods
- Utilize SPC for monitoring performance
- Collect, track & analyze defects
- Schedule regular equipment PM's
- Follow PM's with Cpk MCA testing to validate machine quality performance

What is MCA testing

- Machine Capability Analysis
- 3rd party evaluation of accuracy & repeatability
- Suitable measurement metrology offering flexibility and mobility
- Measure capabilities according to OEM quality performance specifications

MCA Applications

- Screen Printers
- Dispensers
- Chip Shooters
- Fine/Flex Place
- Feeders
- Reflow Ovens
- Board Routers
- Stencil mfg. lasers
- PCB Photo plotters
- Drilling machines
- Laser Marking Systems
- AOI/AXI
- Selective Solder

Y-MCA?

- 85% of 10,000 machines FAILED initially
- Improve machine efficiency rates
- Significant defect reduction
- Increase yield – rates up to 25 %
- Minimize repair time and cost with accurate diagnostics
- Reduce operator intervention
- Validate PM before production startup

How is MCA performed

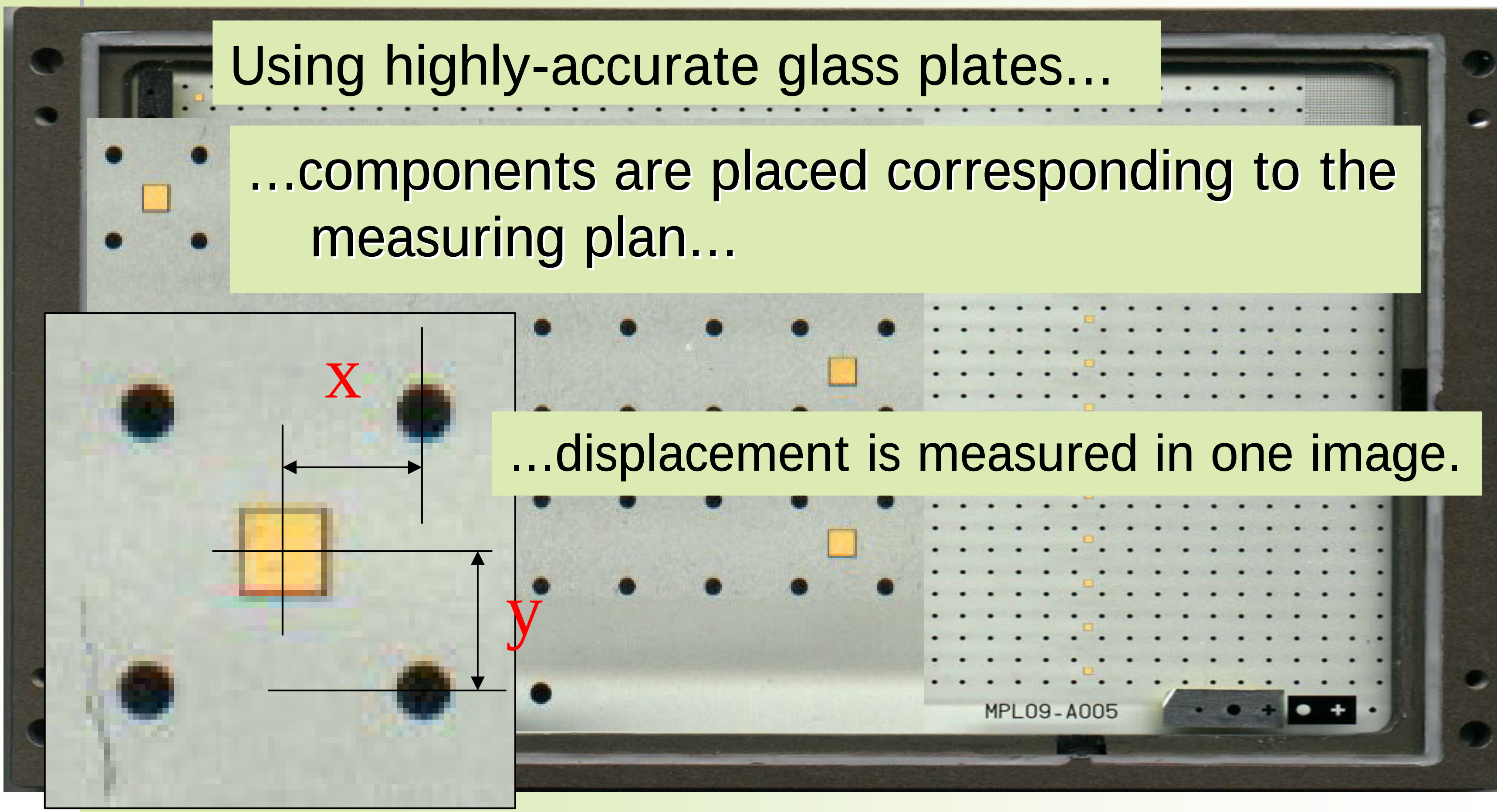
- Design plan to functionally test all aspects of machine.
- Use traceable gauges.
- Run machine like in production.
- Measure actual performance.
- Correlate results to specifications
- Determine how to improve accuracy.

Relative Principle

Using highly-accurate glass plates…

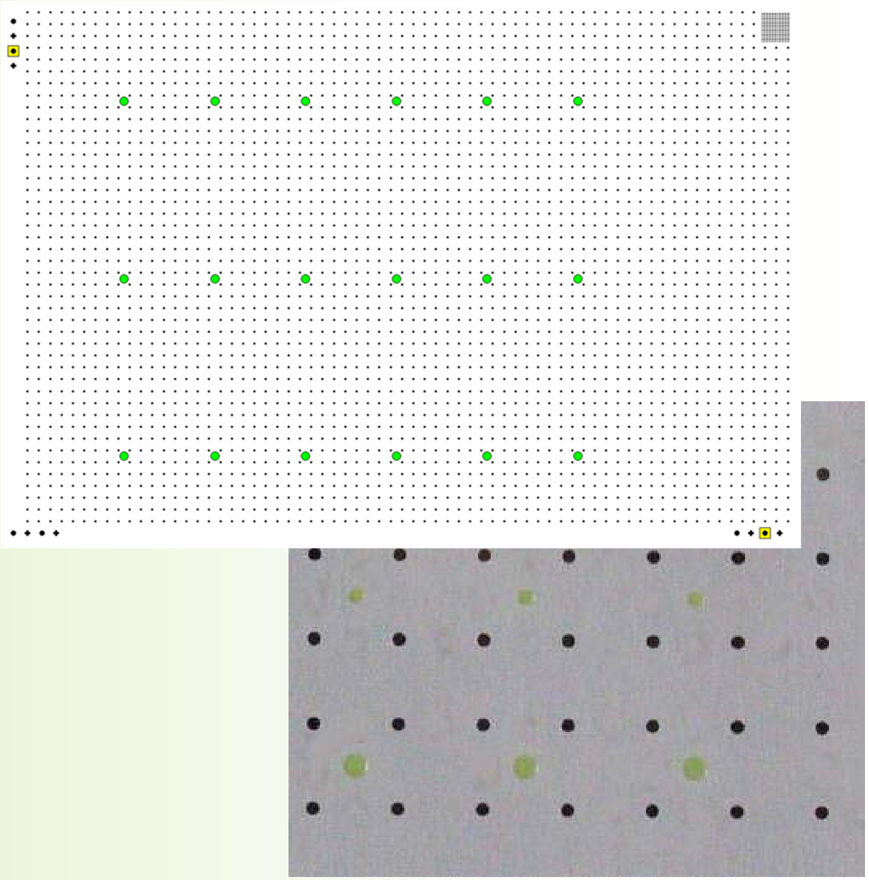
…components are placed corresponding to the measuring plan…

…displacement is measured in one image.

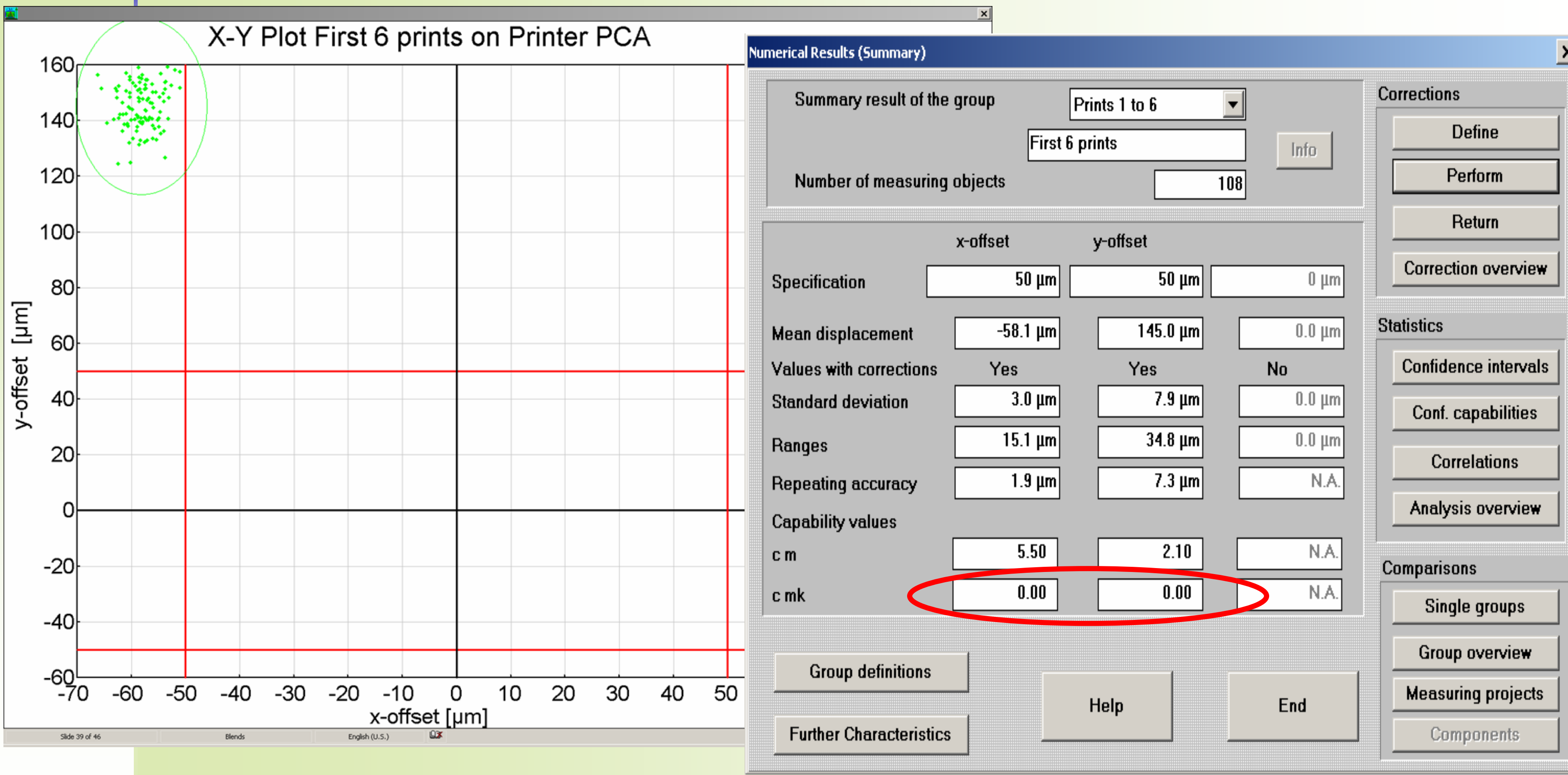


Printer Test Plan (PCA)

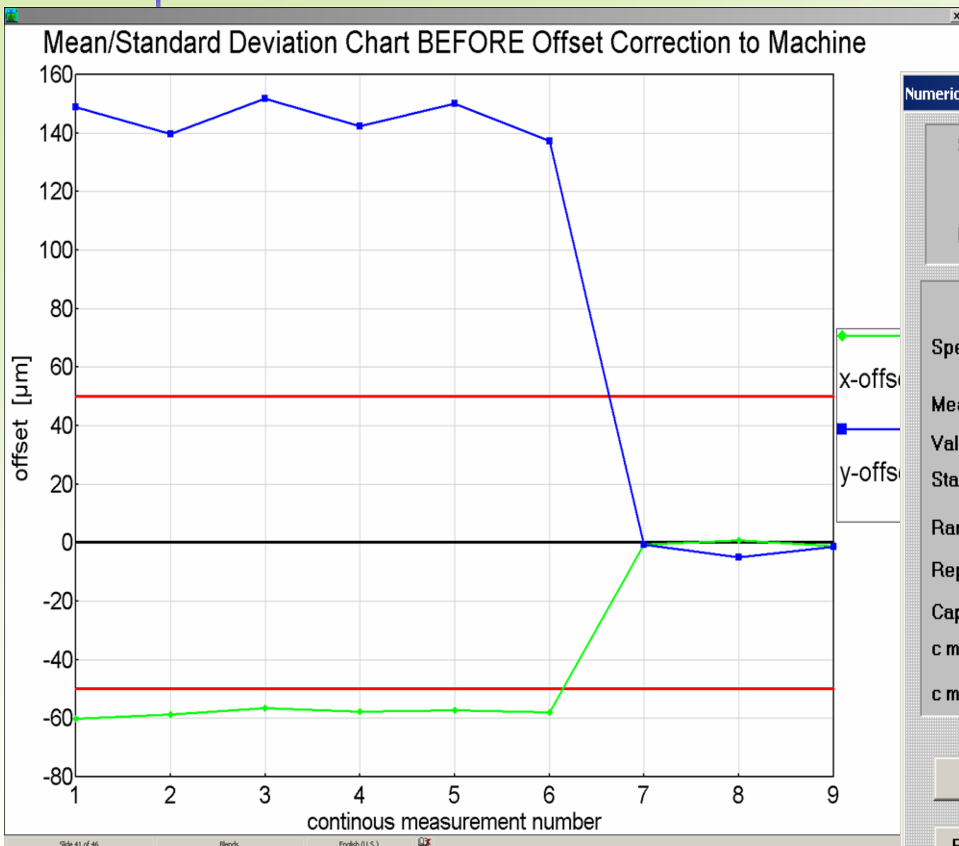
- Print on highly accurate glass plates
- 18 measured points
- 20 machine cycles
- 360 data points
- Strokes grouped
- Typical specs:
  - +/- 50 µm @ 4 Sigma

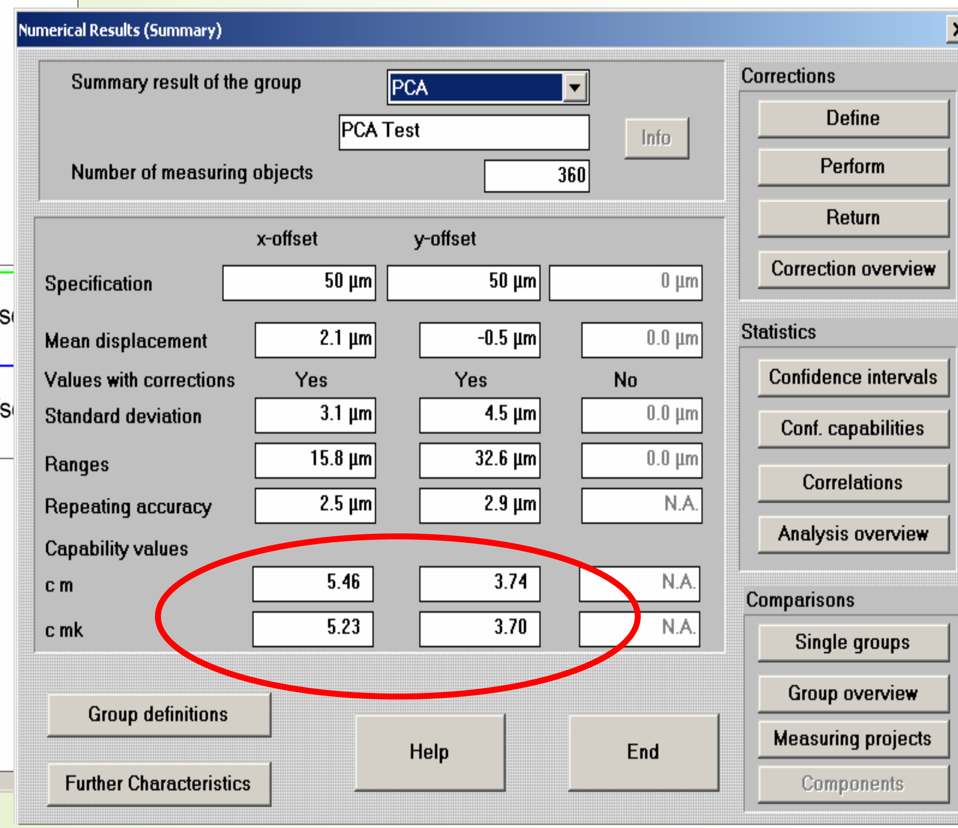


Printer Initial Results



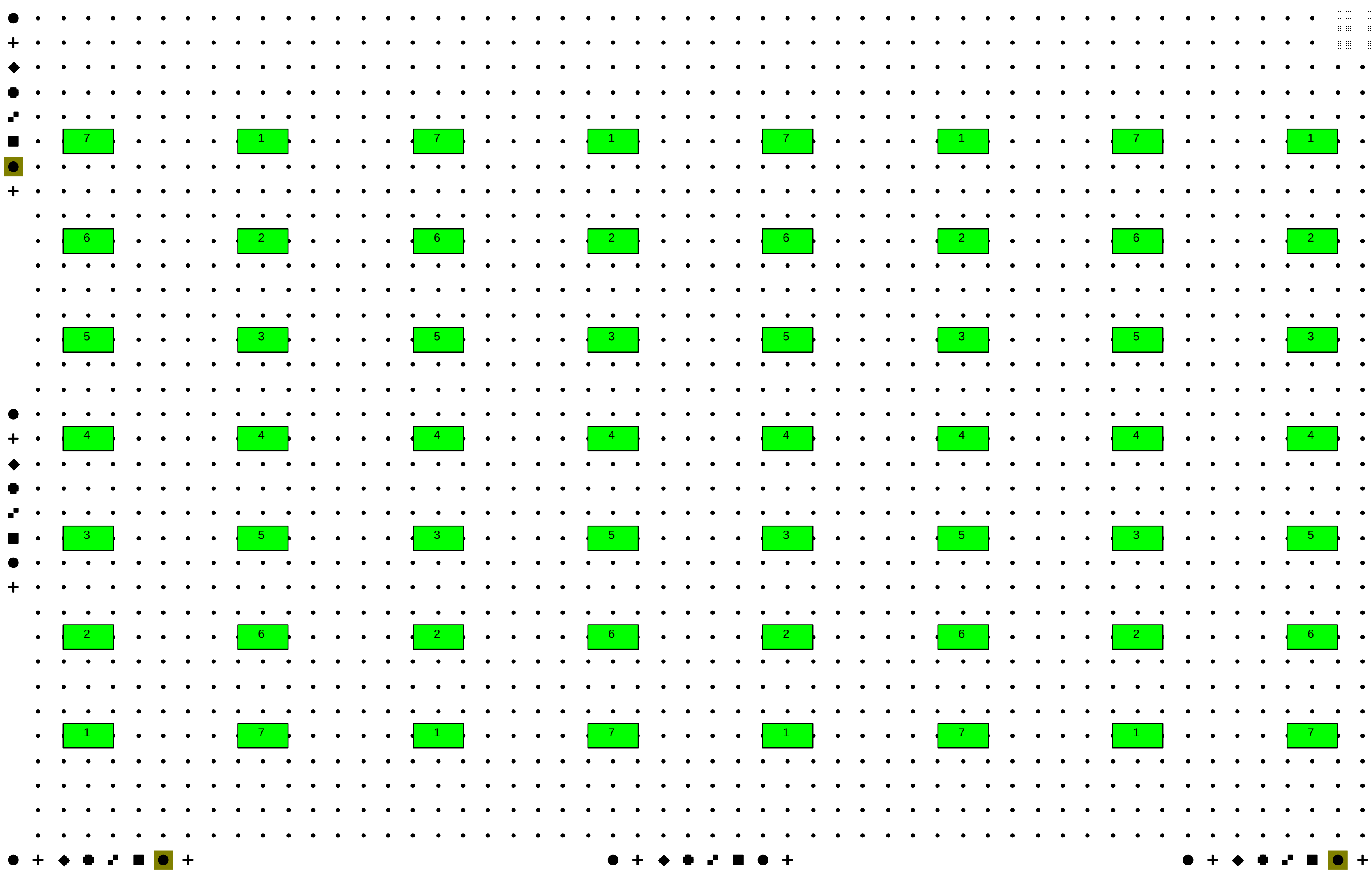
Printer Optimized Results

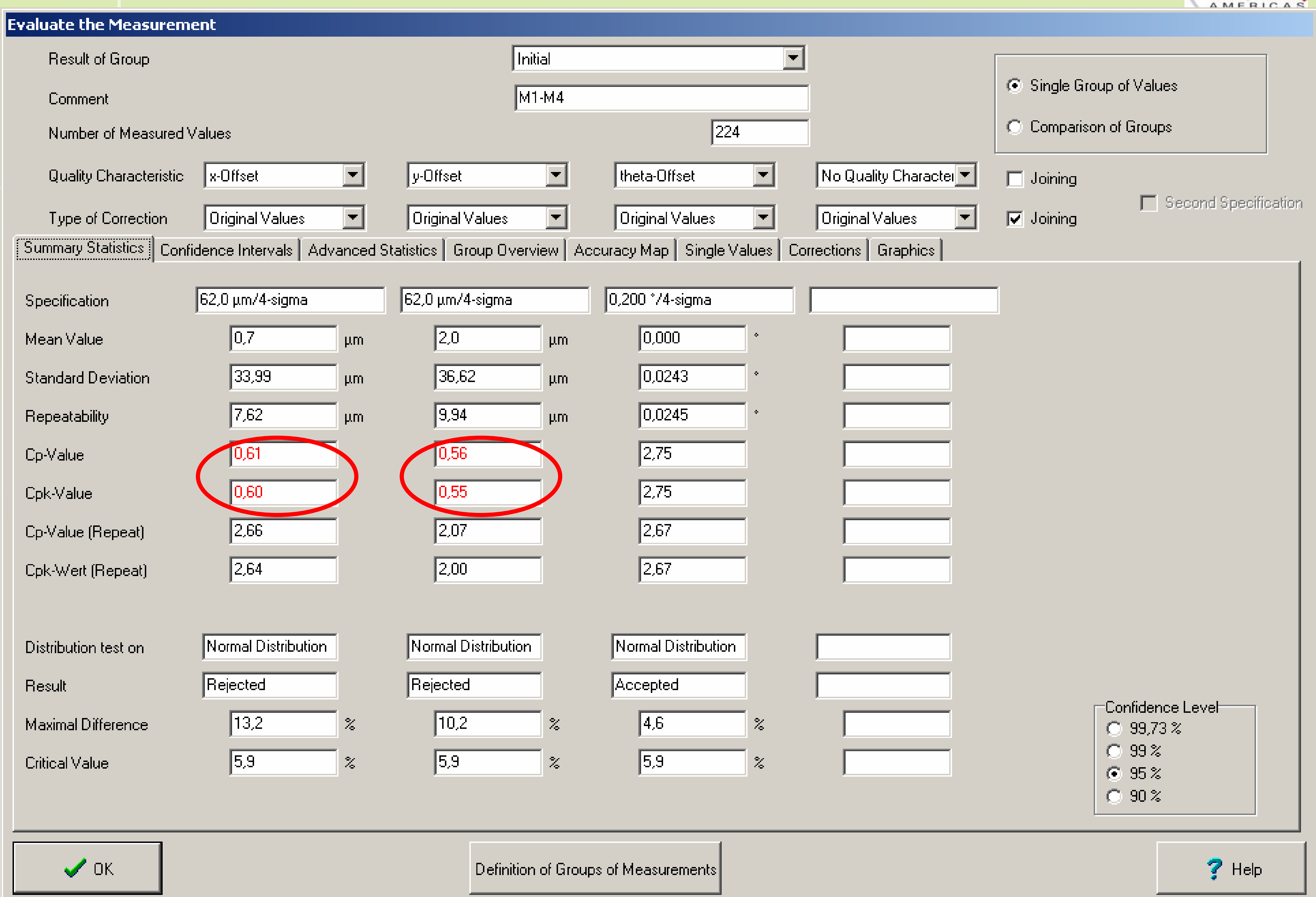




Fine Pitch Placement

- Optimization Example
- Test with TQFP100 Glass Slugs
- Board to Board Measurement
- Spec.: +/- 62 µm +/-0.2° at 4 Sigma
- Acceptable Cpk >1.33


7 1 7 1 7 1 7 1
6 2 6 2 6 2 6 2
5 3 5 3 5 3 5 3
4 4 4 4 4 4 4 4
3 5 3 5 3 5 3 5
2 6 2 6 2 6 2 6
1 7 1 7 1 7 1 7



Evaluate the Measurement

Result of Group	Initial
Comment	M1-M4
Number of Measured Values	224

(•) Single Group of Values
( ) Comparison of Groups

Quality Characteristic	x-Offset	y-Offset	theta-Offset	No Quality Characte
Type of Correction	Original Values	Original Values	Original Values	Original Values

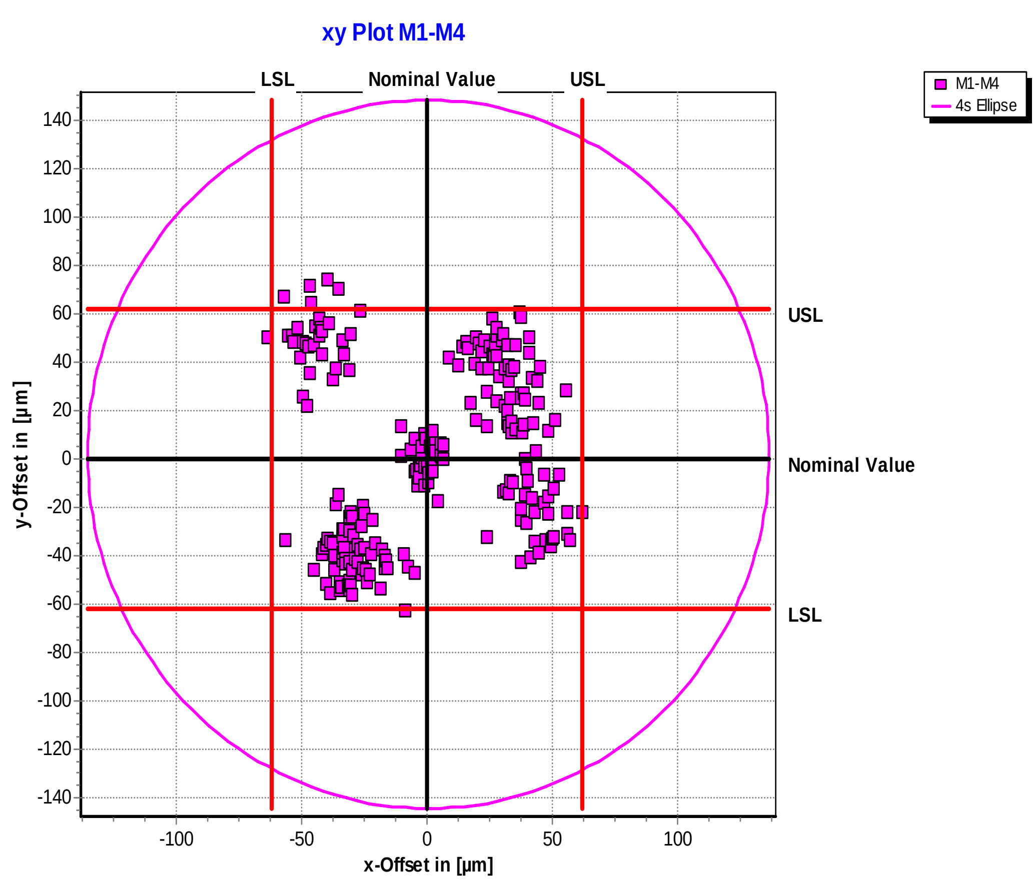
[ ] Joining
[x] Joining
[ ] Second Specification

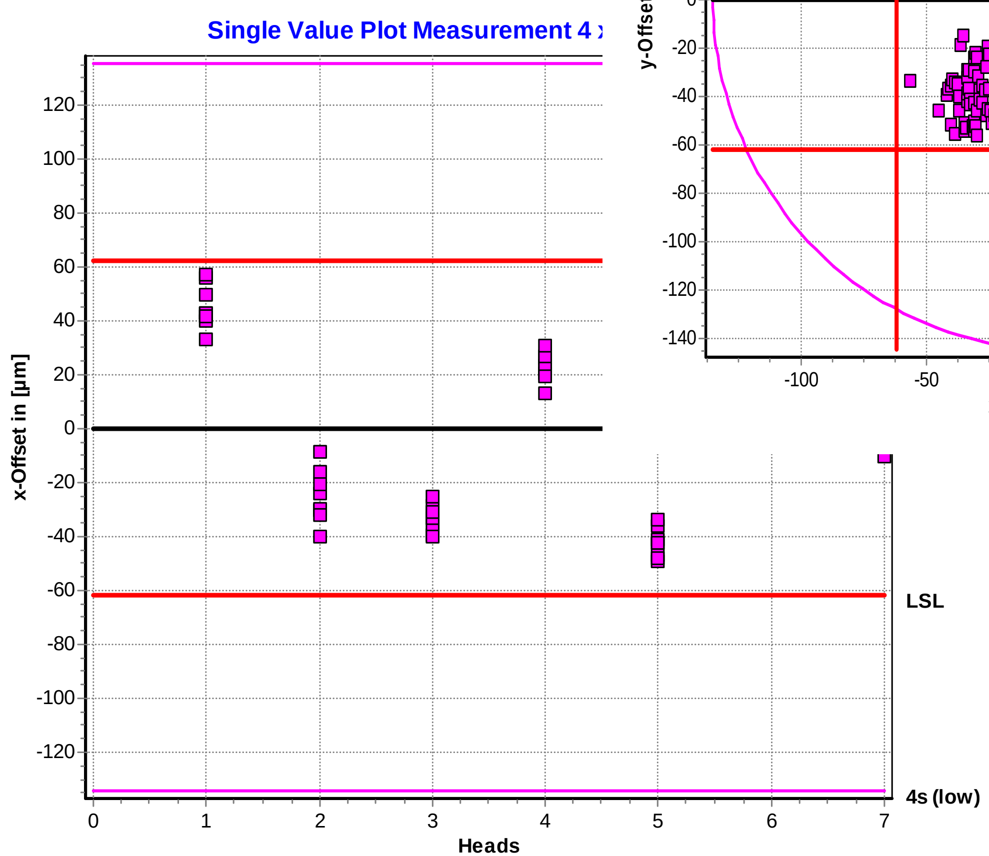
Summary Statistics | Confidence Intervals | Advanced Statistics | Group Overview | Accuracy Map | Single Values | Corrections | Graphics

Specification	62,0 µm/4-sigma	62,0 µm/4-sigma	0,200 °/4-sigma	
Mean Value	0,7 µm	2,0 µm	0,000 °	
Standard Deviation	33,99 µm	36,62 µm	0,0243 °	
Repeatability	7,62 µm	9,94 µm	0,0245 °	
Cp-Value	0,61	0,56	2,75	
Cpk-Value	0,60	0,55	2,75	
Cp-Value (Repeat)	2,66	2,07	2,67	
Cpk-Wert (Repeat)	2,64	2,00	2,67	
Distribution test on	Normal Distribution	Normal Distribution	Normal Distribution	
Result	Rejected	Rejected	Accepted	
Maximal Difference	13,2 %	10,2 %	4,6 %	
Critical Value	5,9 %	5,9 %	5,9 %	

Confidence Level
( ) 99,73 %
( ) 99 %
(•) 95 %
( ) 90 %

OK | Definition of Groups of Measurements | Help


xy Plot M1-M4
LSL
Nominal Value
USL
M1-M4
4s Ellipse
USL
Nominal Value
LSL
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
y-Offset in [µm]
-100
-50
0
50
100
x-Offset in [µm]


Single Value Plot Measurement 4 x
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
x-Offset in [µm]
LSL
4s (low)
0
1
2
3
4
5
6
7
Heads

CeTaQ AMERICAS

Evaluate the Measurement

Result of Group: Final

Comment: M5-M8

Number of Measured Values: 224

(•) Single Group of Values
( ) Comparison of Groups

Quality Characteristic	x-Offset	y-Offset	theta-Offset		[ ] Joining
Type of Correction	Original Values	Original Values	Original Values	Original Values	[x] Joining

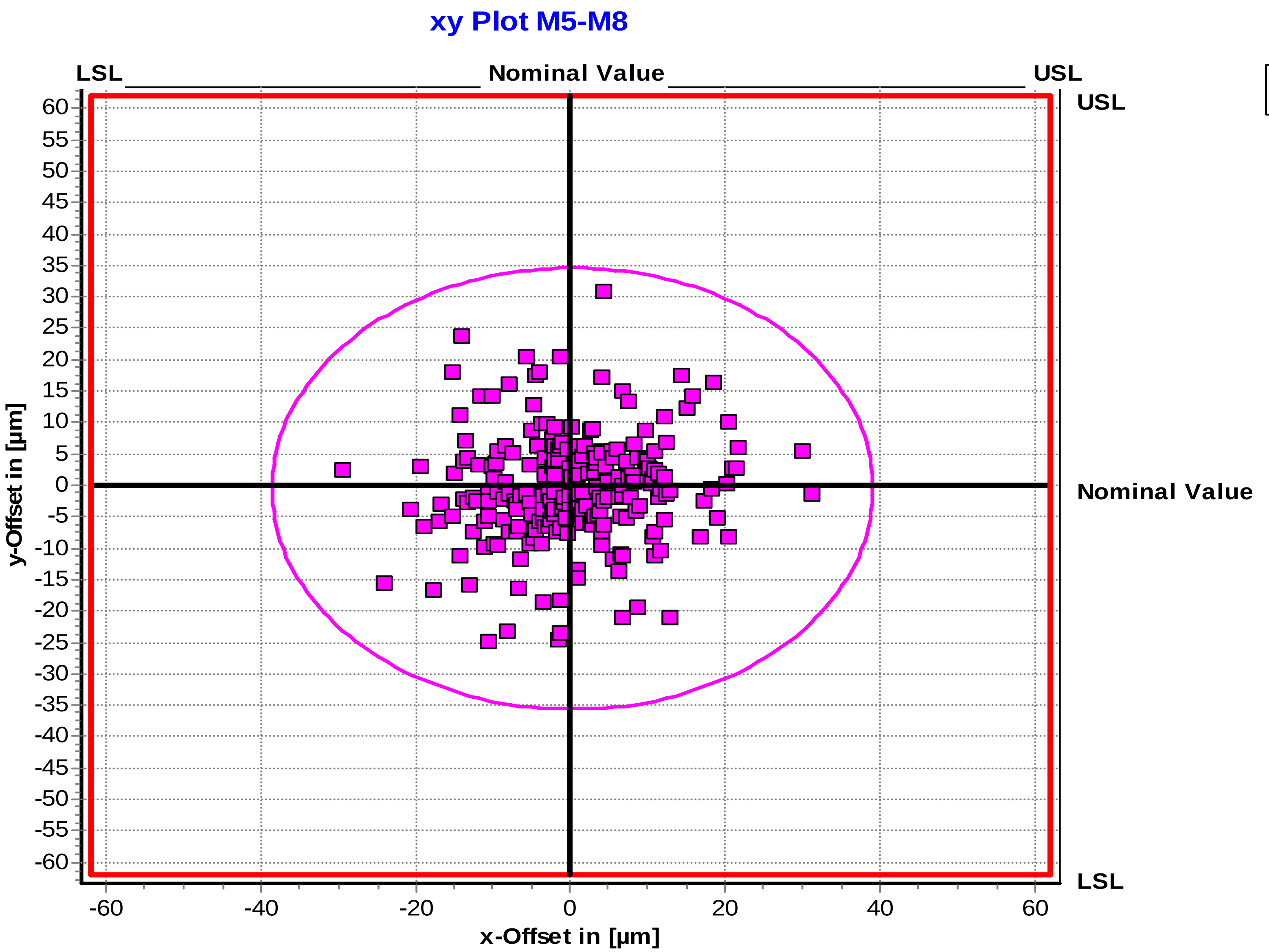
[ ] Second Specification

Summary Statistics | Confidence Intervals | Advanced Statistics | Group Overview | Accuracy Map | Single Values | Corrections | Graphics

Specification	62,0 µm/4-sigma	62,0 µm/4-sigma	0,200 °/4-sigma	
Mean Value	0,3 µm	-0,5 µm	0,002 °	
Standard Deviation	9,71 µm	8,78 µm	0,0258 °	
Repeatability	8,91 µm	7,99 µm	0,0250 °	
Cp-Value	2,13	2,35	2,59	
Cpk-Value	2,12	2,33	2,56	
Cp-Value (Repeat)	2,31	2,54	2,62	
Cpk-Wert (Repeat)	2,30	2,52	2,59	
Distribution test on	Normal Distribution	Normal Distribution	Normal Distribution	
Result	Accepted	Rejected	Accepted	
Maximal Difference	3,4 %	6,5 %	4,8 %	
Critical Value	5,9 %	5,9 %	5,9 %	

Confidence Level
( ) 99,73 %
( ) 99 %
(•) 95 %
( ) 90 %

OK | Definition of Groups of Measurements | Help



xy Plot M5-M8
LSL
Nominal Value
USL
M5-M8
4s Ellipse
USL
Nominal Value
LSL
60
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40
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y-Offset in [µm]
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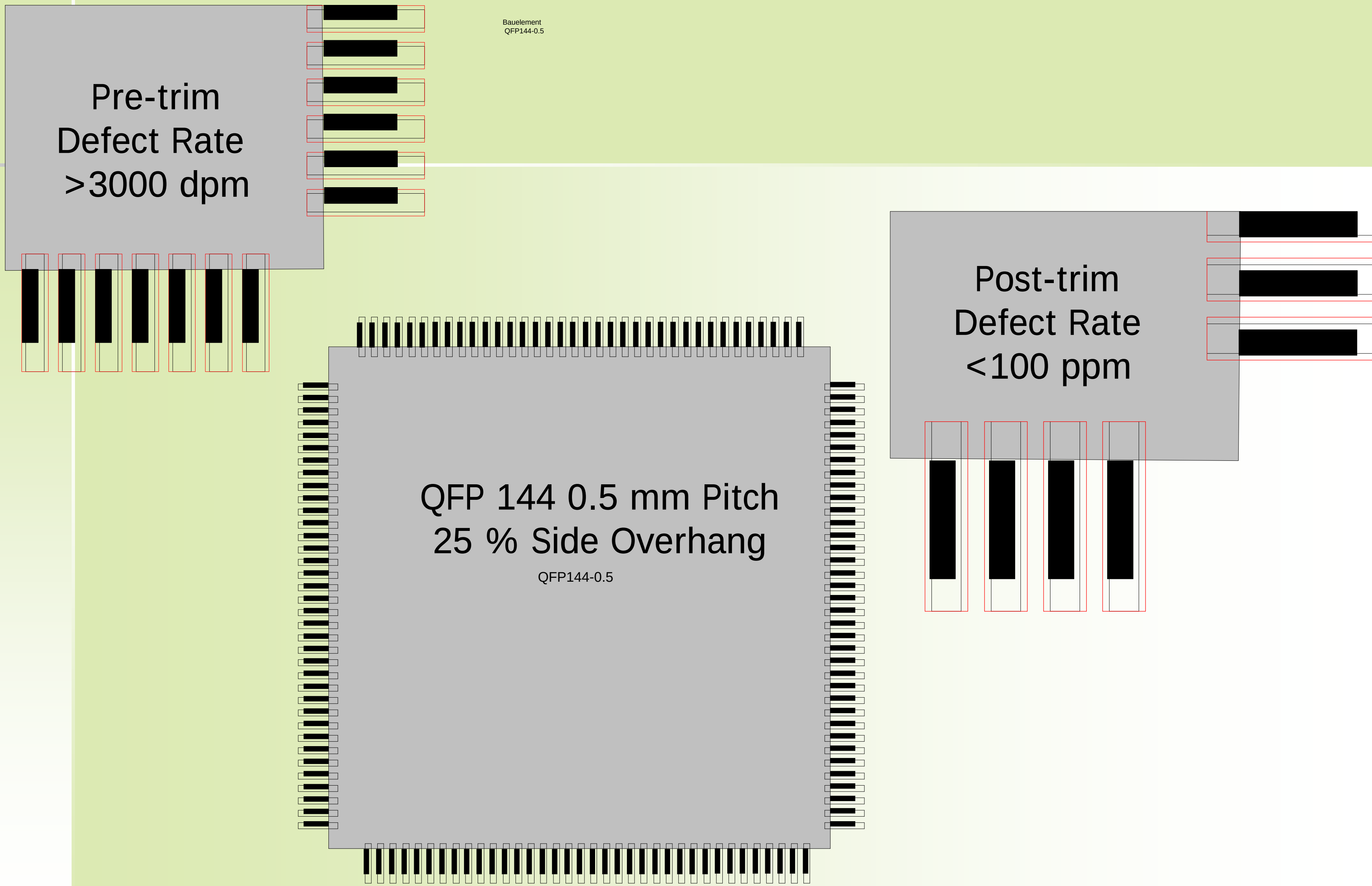
-40
-20
0
20
40
60
x-Offset in [µm]


Pre-trim
Defect Rate
>3000 dpm
Bauelement
QFP144-0.5
Post-trim
Defect Rate
<100 ppm
QFP 144 0.5 mm Pitch
25 % Side Overhang
QFP144-0.5

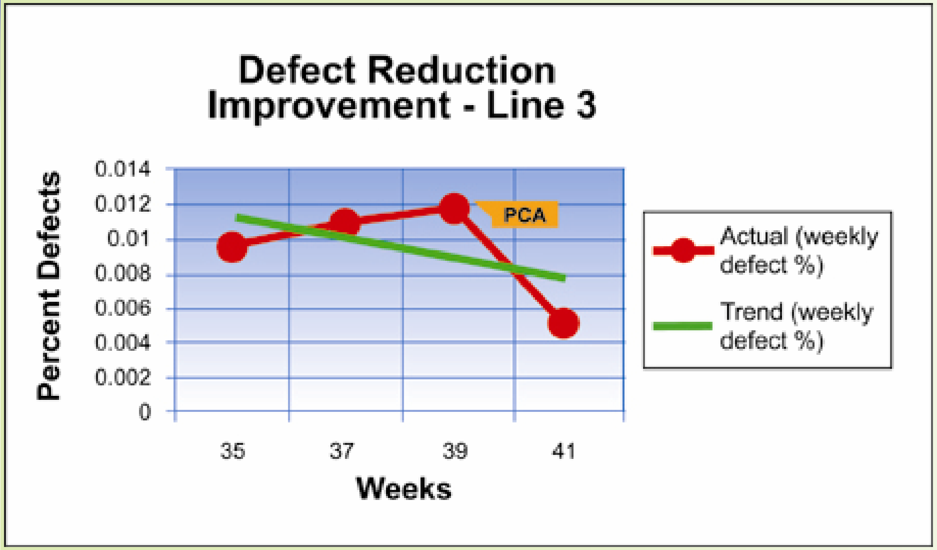
DPM and Cost

- 20,000 units per shift per line
- 3 shifts, 5 days
- $15 repair cost per defect unit
- Reducing defect rate from 3000 to 100 DPM
- Saving of $700,000 per year per line

Advantages of regular MCA tests

- Accuracy improvement of the line = failure cost reduction
- Maintenance coordination = optimization of maintenance costs
- Reduce costs with technology changeovers
- Help make investment decisions
- Acceptance test for new equipment
- Documentation of line accuracy
- Process observation in combination with attributive tests

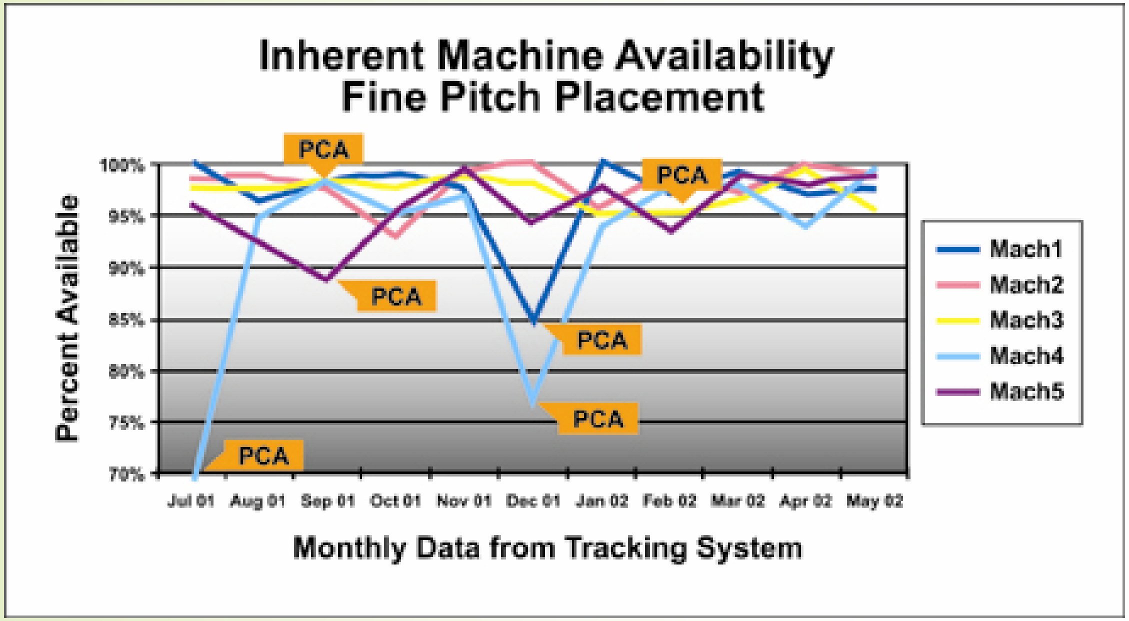
Defect Reduction



- Weeks 39 to 41 show significant defect reduction after optimizing only line 3.
- Consider the impact on multiple lines over the period of 1 year...

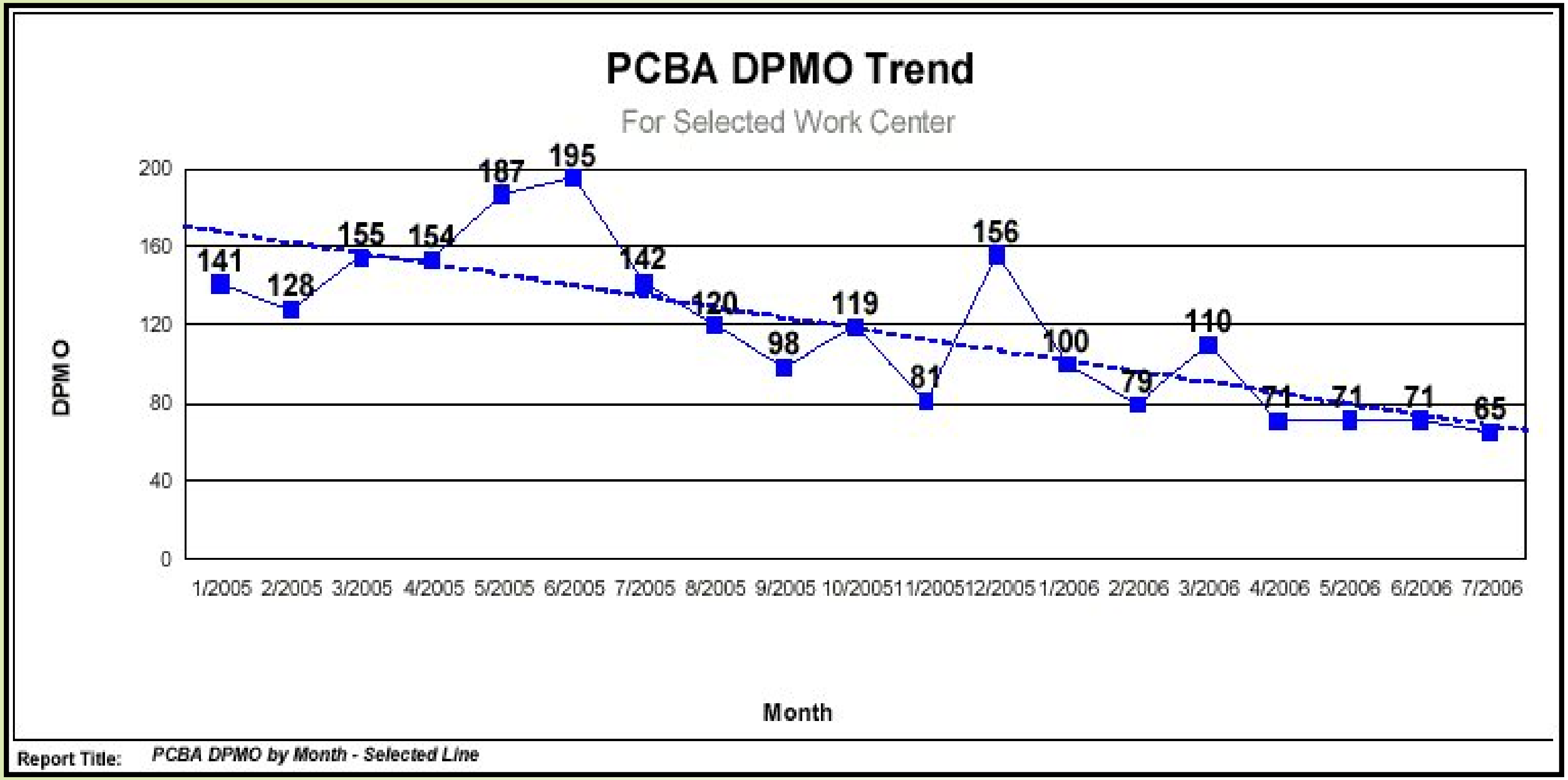
Machine Uptime

- Executing PCA validation tests in the case of this large contract manufacturer, keeps machine uptime above 95%!
- Monthly tests on fine pitch machines yields best results.



DPMO Improvement

- Case study data from high mix low volume PCB assembly shop with regular MCA testing.



Profitability Impact

- Improved machine efficiency and uptime creates additional capacity.
- Reduced defects saves rework costs and yields customer satisfaction.
- Each element contributes to:
- INCREASED PRODUCTIVITY, which has a penetrating effect on PROFITABILITY.

Summary

- Statistical measurement of machine capability is a sure way of having confidence in overall product quality as it relates to accuracy and repeatability.
- Automation and 6 Sigma quality initiatives will play a large role in sustaining domestic manufacturing.

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Thank You!