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Semiconductor Wafer Test Workshop

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Use of On-Line Probe-To-Pad Alignment (PTPA) Data To Improve Test Cell Performance

Outline

- Intro to PTPA Data
  - Description and Benefits using PTPA Data
- PTPA Derived Planarity
  - Tilt
  - Curvature
- PTPA Derived Temperature Dependent Parameters
  - Scaling Rate, Total Scaling and Scaling Coefficient
  - X and Y Estimated Error
- PTPA Database
  - PTPA Data Management and Uses

Intro to PTPA Data

Description of PTPA Data

- PTPA Data is the data log generated by the prober while optically aligning a sample of probe tips in a Probe Card, to the corresponding X,Y,Z bond pad locations on product wafer.
- Sample of information in these files:
  - X_Err, Y_Err, Z_Err (Error of point in 3-D space)
  - Probe Tip Area
  - Probe Card Center, Wafer Center
  - Wafer Thickness
  - Contact Height
- By combining these datasets with other known Probe Card data, other critical information may be derived such as:
  - Planarity (Tilt, Curvature)
  - Scaling (Total, Rate, Coefficient)
  - X and Y Estimated Placement Error

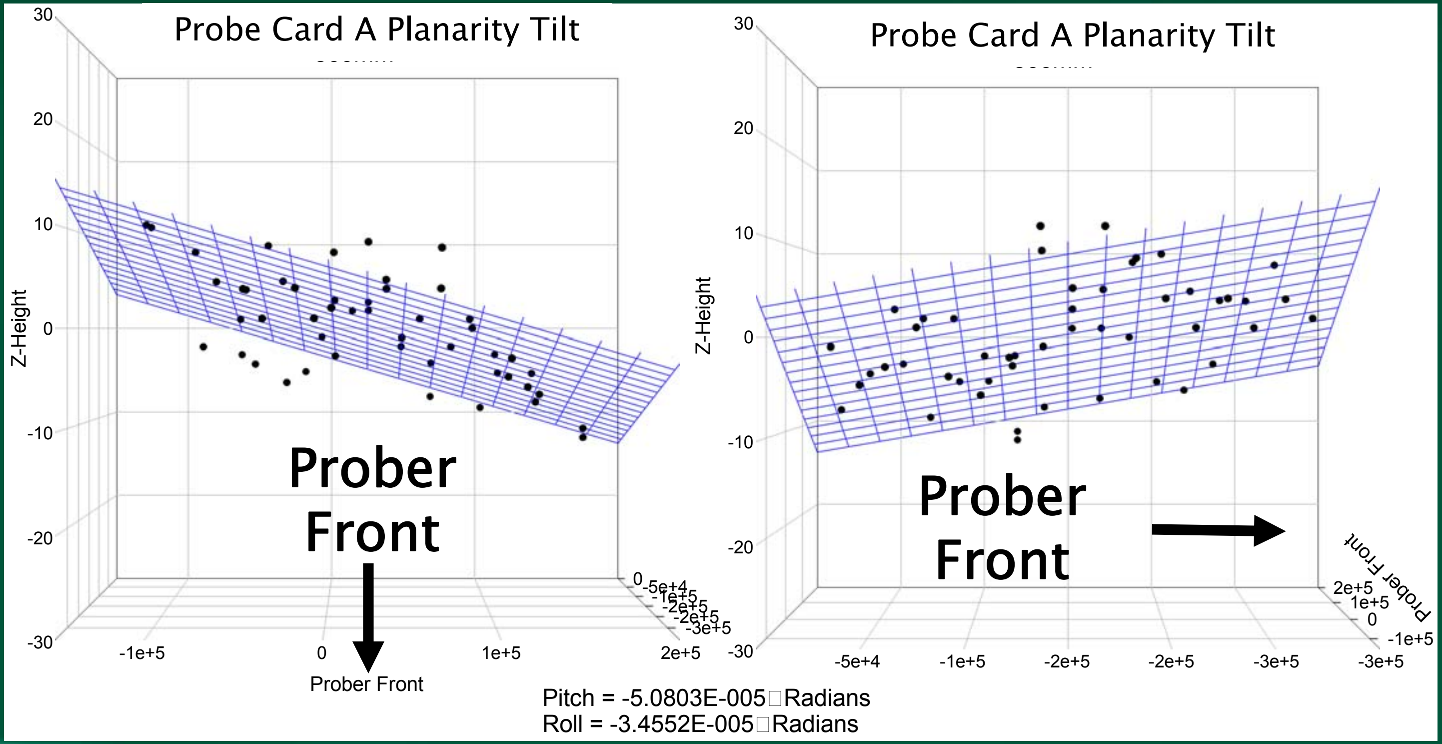
Uses and Benefits of PTPA Data

- Many of the challenges that came about with the increasing sizes of Probe Cards were alleviated.
- 300mm Probing process needs require refined criteria to avoid the following:
  - Yield Loss and Probe Card Damage due to Poor Planarity
  - Downgraded or scrapped product due to Out of control Temperature Dependent Parameters
    - Bond Pad Edge Infringement zone violations
- Qualification of large array Probe Cards has enabled successful one touchdown Probing on 300mm wafers at Micron!!.

PTPA Derived Planarity
(Tilt, Curvature)

PTPA Derived Planarity Tilt

- With PTPA data, a complete X,Y,Z plot with a Best Fit Plane may be generated with Pitch and Roll angular measurements.
  - Pitch and Roll represent the X and the Y Axis respectively



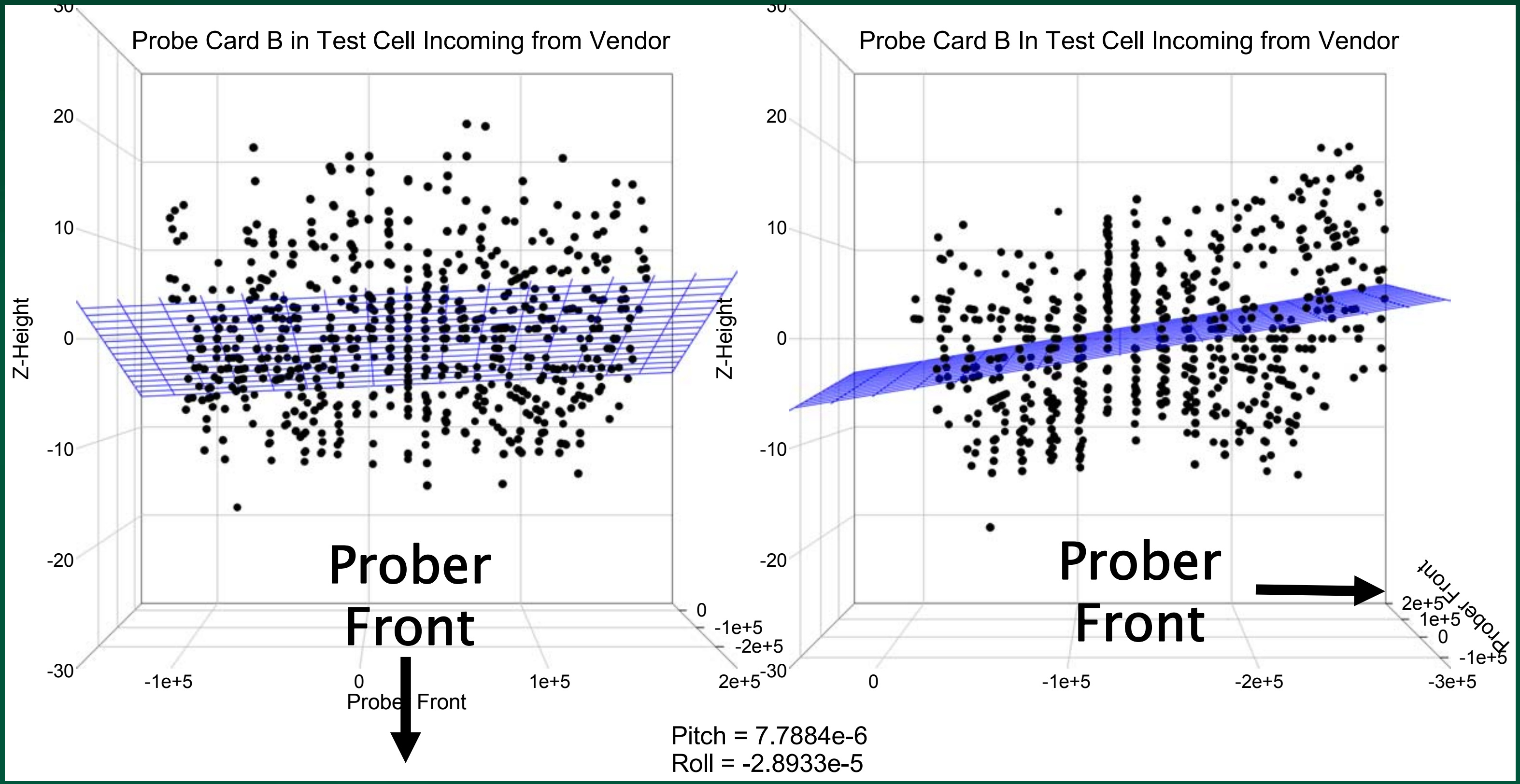
- By applying these concepts, Planarity Tilt has magnitude and direction, therefore Planarity results are not subjective.

Planarity Tilt Issues

- Planarity Tilt on 300mm Probe Cards becomes a more critical factor to overcome.
- To address this issue:
  - Normalized the Pitch and Roll polarities and orientations between Metrology Tools and Test Cells (PTPA)
  - Correlated Probe Cards, Test Cells and Metrology Tools to a “Golden” Pitch and Roll signature
  - Planarity Data from Test Cells is logged and re-verified any time out of spec conditions are experienced
- Because of this activity:
  - Probe Card damage and Yield Loss due to Planarity Tilt is minimized
  - Probe Cards can be moved between Test Cells, and Metrology tools, without the need to re-planarize

Other Applications of Planarity Tilt

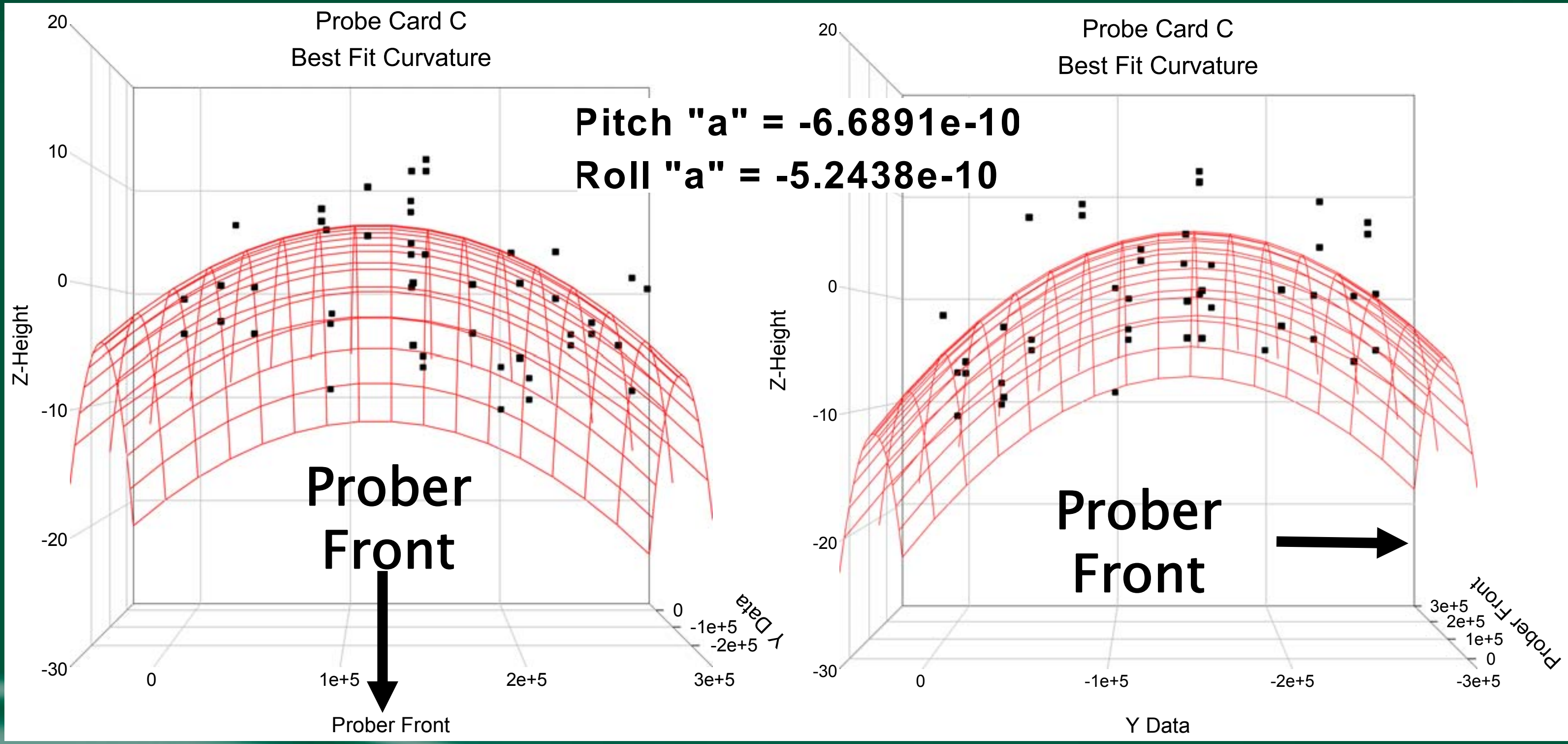
- One supplier used this Planarity Tilt “Golden” signature method.



- Probe Card technology is within spec conditions out-of-the-box! There is no need to planarize Probe Cards from this supplier.

PTPA Derived Planarity Curvature

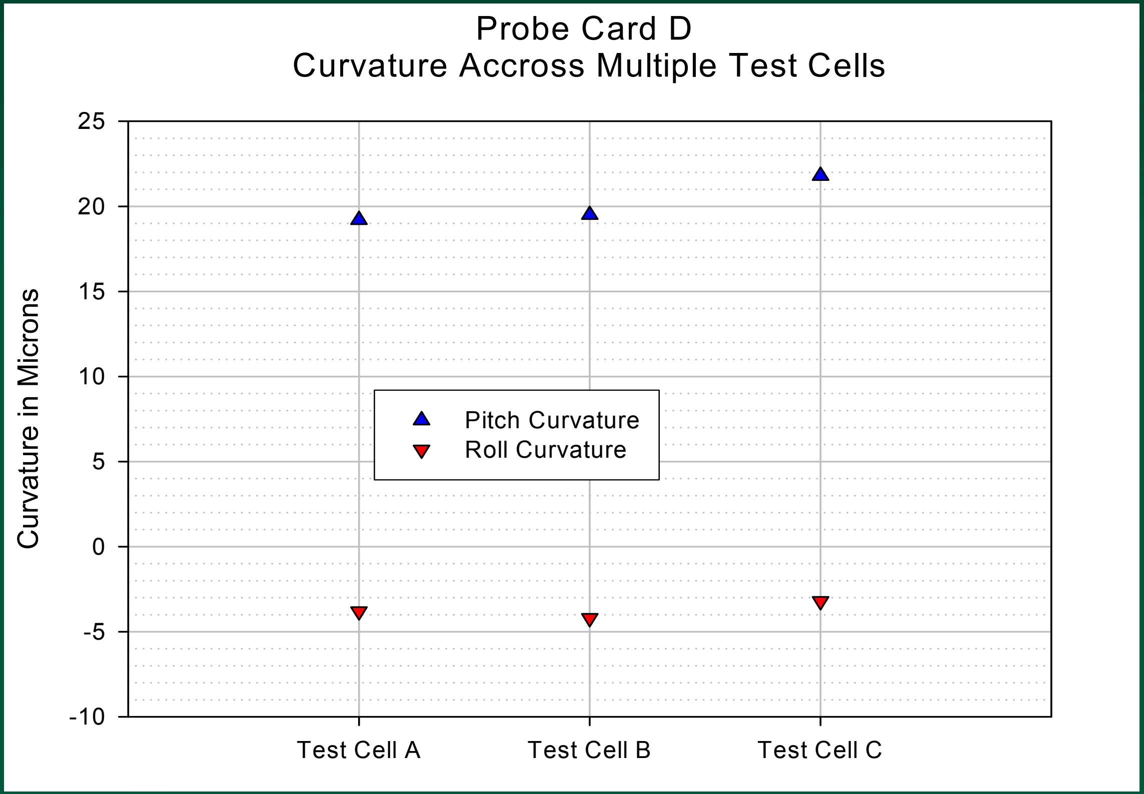
- While Planarity Tilt is defined thru a Best Fit Linear Plane (first order regression), Curvature may be defined thru a Quadratic Best Fit Plane (second order regression)



*Refer to Appendix A for more information on Planarity Curvature.

Uses of Planarity Curvature

- Used to characterize and compare Test Cell, Metrology or Probe Card induced Curvature issues



- Probe Card D shows Positive Curvature on the Pitch, which is seen across multiple Test Cells.
- This Curvature problem can be traced to the Probe Card.

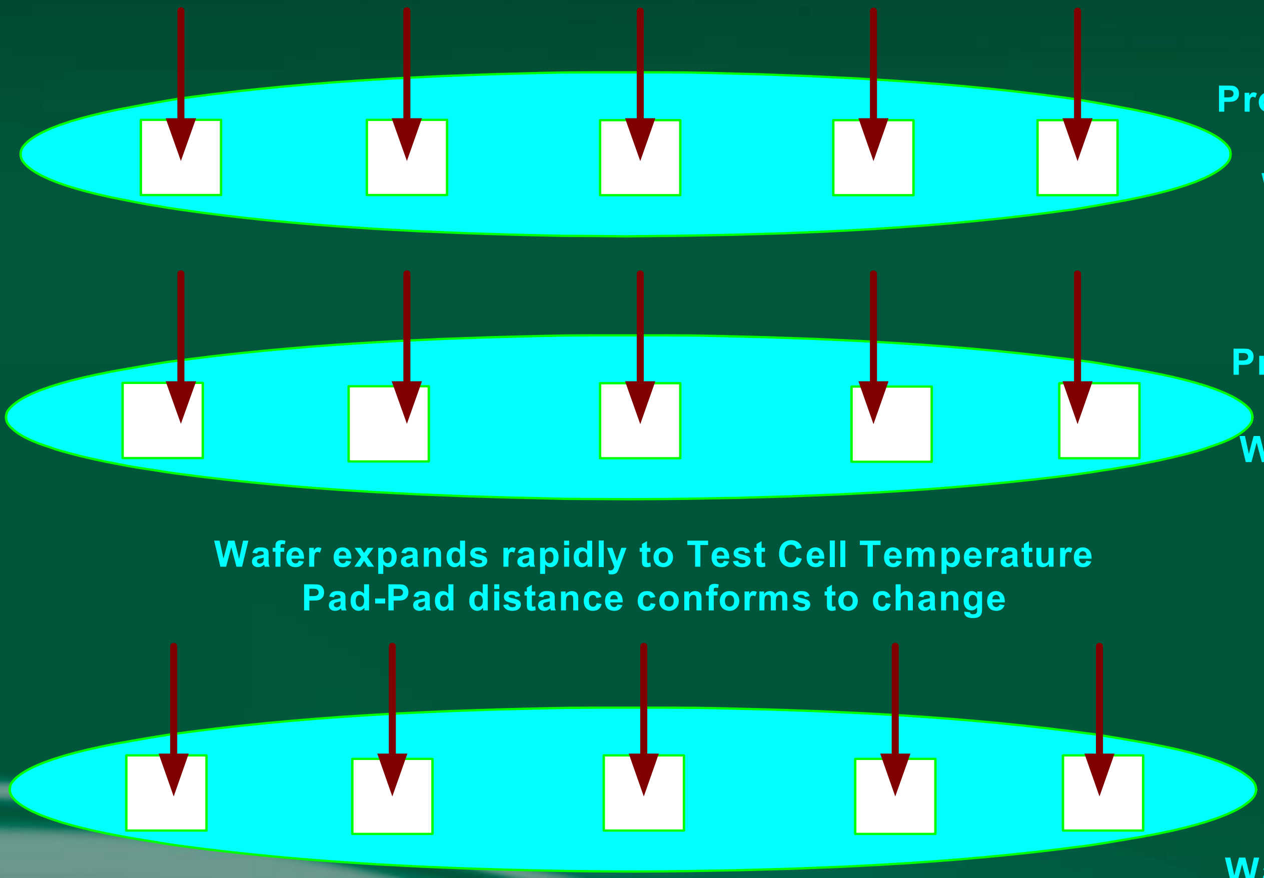
PTPA Derived Temperature Dependent Parameters

Temperature Dependent Parameters

- Probe Cards typically experience different thermal states in a normal production environment.
- With the different Thermal States, there are several Probe Card aspects to be considered.
- Scaling:
    - The concept of Scaling could be defined as the averaged X and Y error across a Probe Card axis
        - Scaling Rate
        - Total Scaling
        - Scaling Coefficient/Temperature
- X and Y Placement Error:
    - Error may be estimated thru Normal Cumulative Distributions

PTPA Thermal Compensation

- Prober automatically compensates for Si Wafer expansion, PTPA data X_Err and Y_Err reflect this compensation



Probe Card = Room Temperature
Wafer = Room Temperature

Probe Card = Room Temperature
Wafer = Operating Temperature

Wafer expands rapidly to Test Cell Temperature
Pad-Pad distance conforms to change

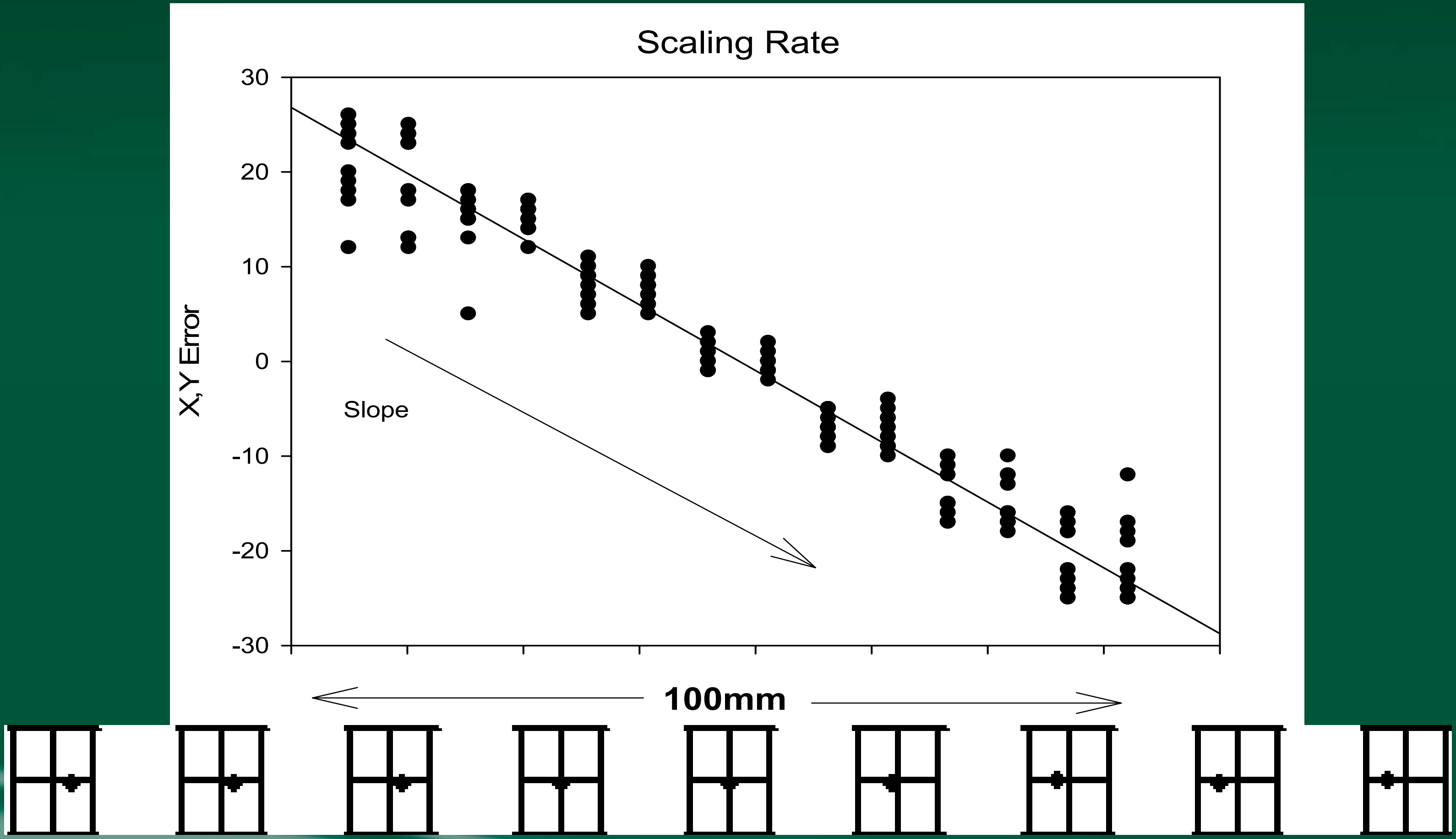
Probe Card = Operating Temperature
Wafer = Operating Temperature

Probe Card expansion rate depends on technology

Scaling

Scaling Rate

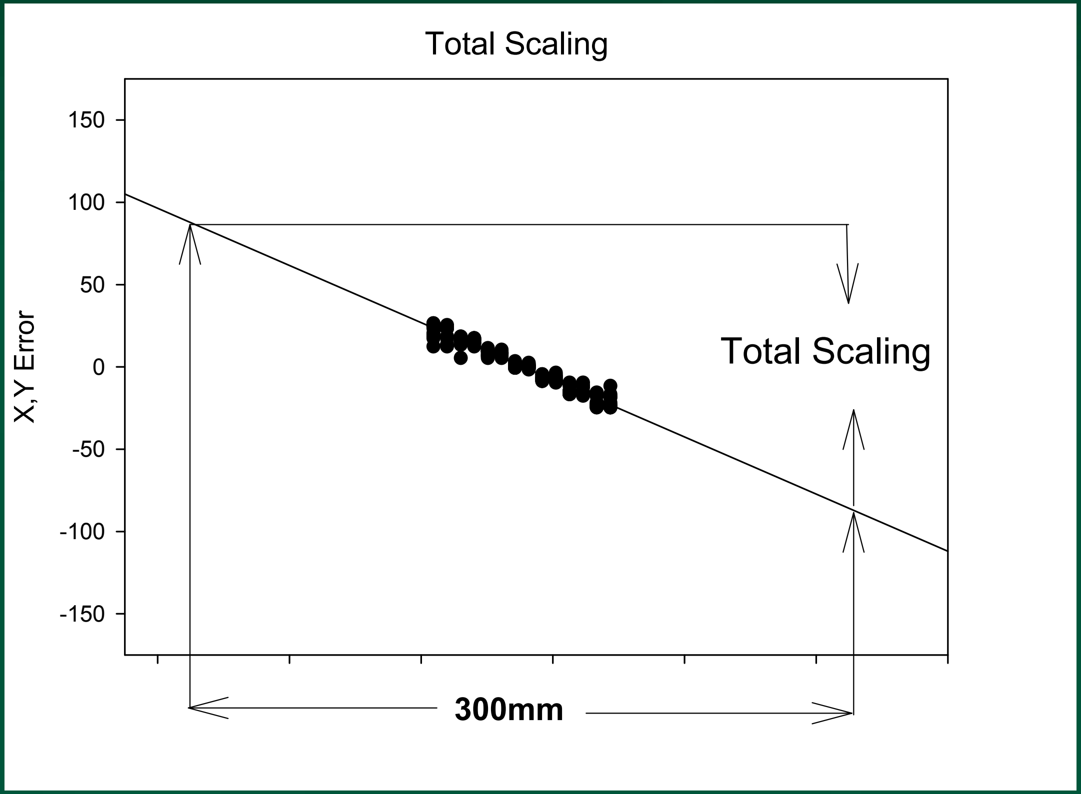
- Main purpose of Scaling Rate is to normalize Scaling values to a common Probe Card size.



*Refer to Appendix C for more information on Scaling Rate.

Total Scaling

- Total Scaling is the total projected error seen within a Probe Card array.



- This could be used to extrapolate if probe tips would violate Bond Pad Infringement Zones.

  *Refer to Appendix C for more information on Total Scaling.

Scaling Coefficient/Temperature

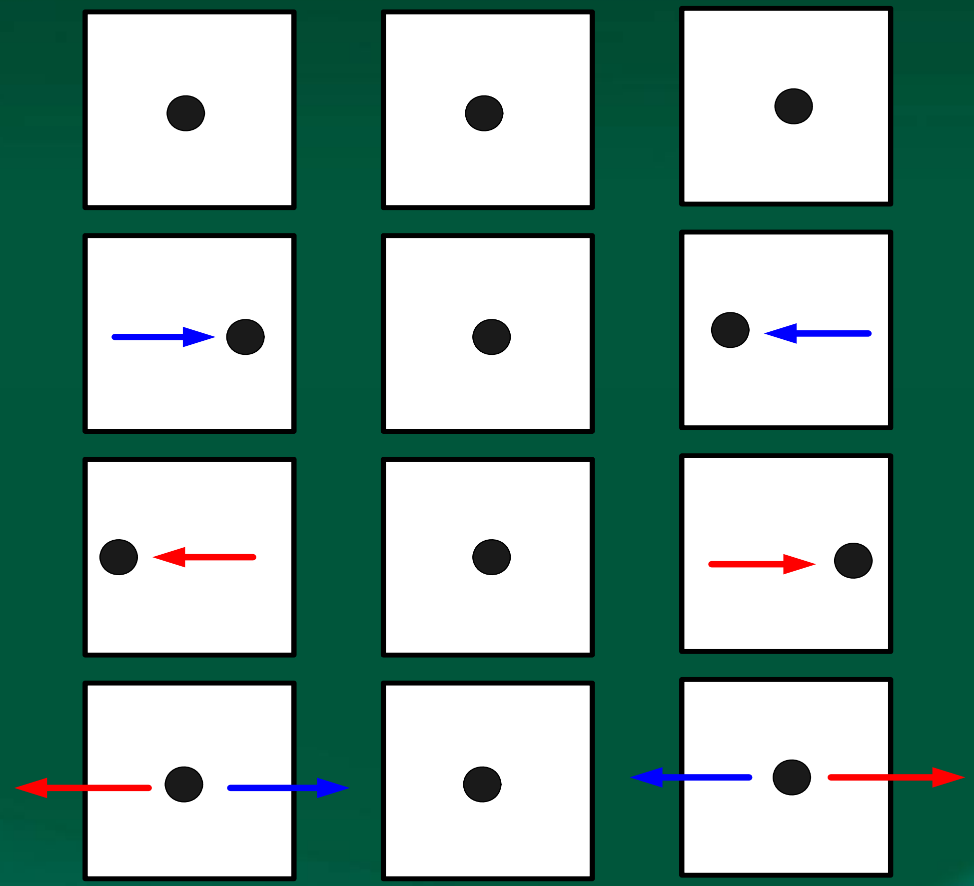
- Defined as changes of scaling due to changes in temperature.

Optimal Scaling scenario (Room Temperature Probe Card in Room Temperature Test Cell

Scaling with cold Probe Card

Scaling with hot Probe Card

Scaling can be calculated for different operating temperatures



*Refer to Appendix D for more information on Scaling Coefficient/Temperature

Scaling Summary

- Scaling will vary over different thermal scenarios.
- Scaling Rate is typically dependent to each Probe Card design.
- Total Scaling value is dependent on Probe Card size.
- Scaling Coefficient/Temperature is dependent to a Probe Card technology.
- Supplier may add a Scaling Offset to a Scaling signature
- Scaling Coefficient/Temperature can help predict Scaling behavior of a technology during different thermal scenarios.
- These parameters can be used to determine if a technology will meet internal roadmap needs.

X and Y Placement

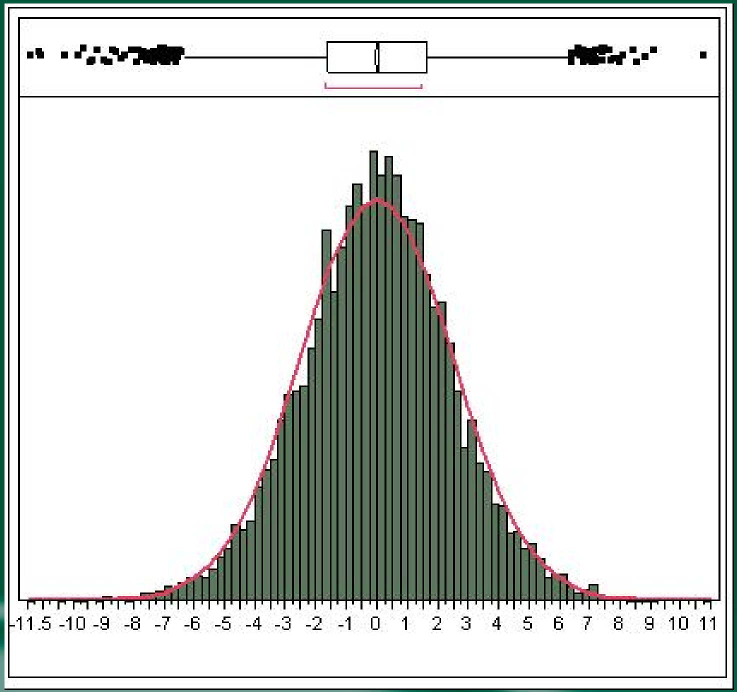
X and Y Placement Challenges

- Metrology Tools typically simulate only Room Temperature testing (for both Test Cell and Probe Card); rarely a true production state.
- PTPA Sample sizes are typically < 1% of entire Probe Card
- Scaling Parameters are averaged values and do not account for tip to tip placement error
- R-Squared values from Scaling regressions are rarely > .8
- Standard Deviations and overlays do not account for the entire probe tip population of a probe card

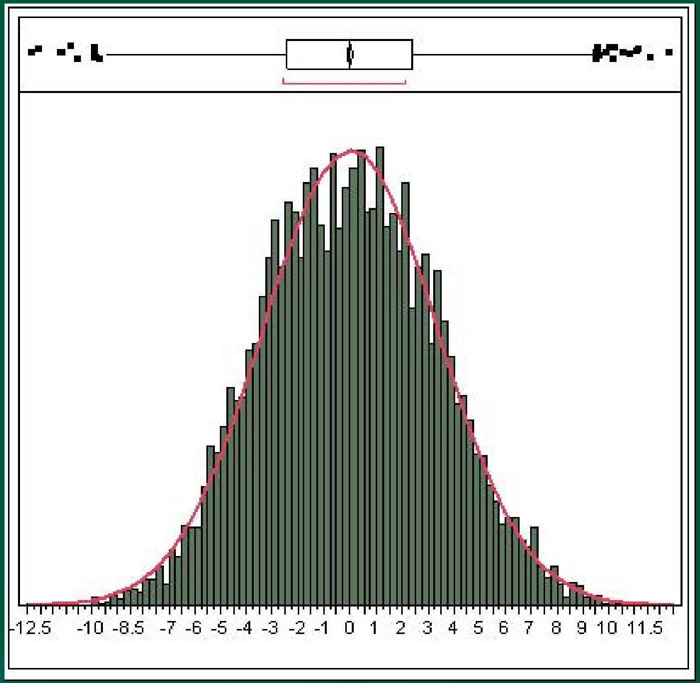
Normal Distributions

- X and Y Placement Error of entire probe tip population in a Probe Card, typically exhibits a Normal Distribution.

Full Probe Card X_Err

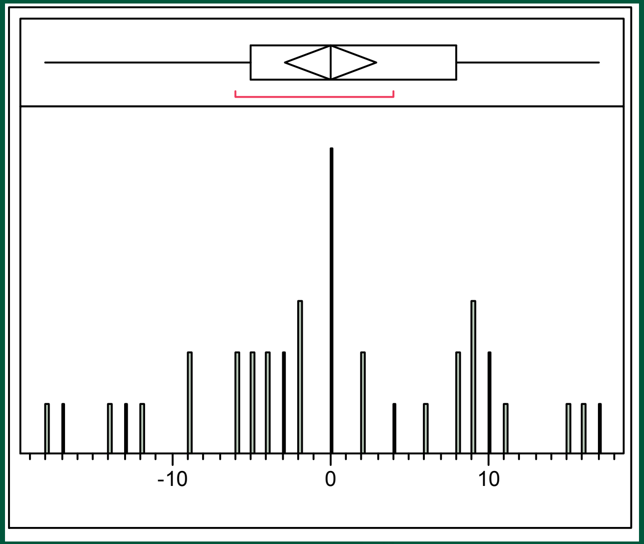


Full Probe Card Y_Err

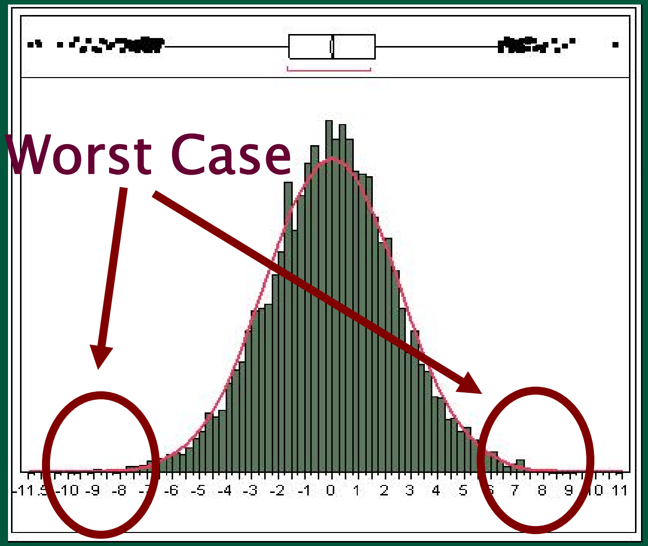


Purpose of Normal Cumulative Distribution

- The main purpose of Normal Cumulative Distributions is to be able to extrapolate to 100% of the population size, based on the results from a sample set, to estimate the worst case scenario X and Y Error.



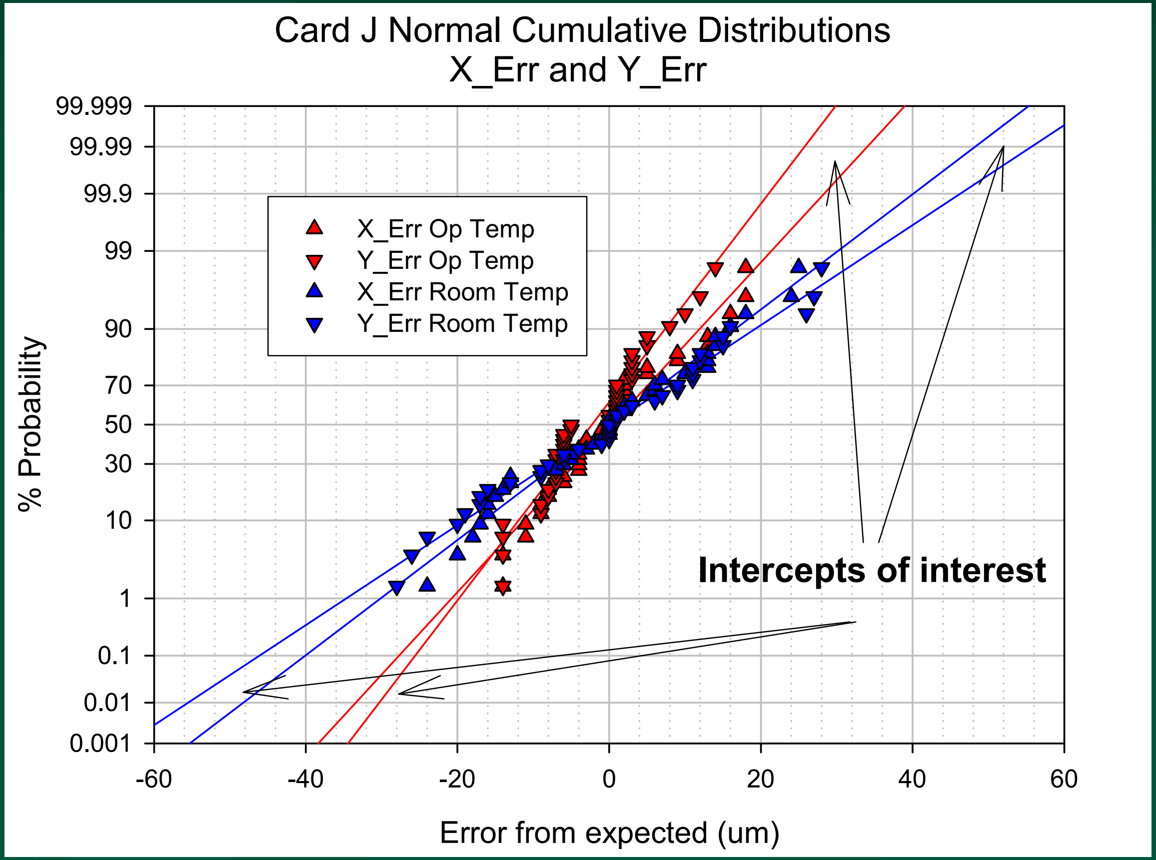
Convert



Sample → Extrapolate → 100%

Example of Normal Cumulative Distribution

- PTPA data from a Probe Card analyzed at two different thermal states.



- X and Y Placement is better when Probe Card is at operating temperature.

*Refer to Appendix E for more information on Normal Cumulative Distributions

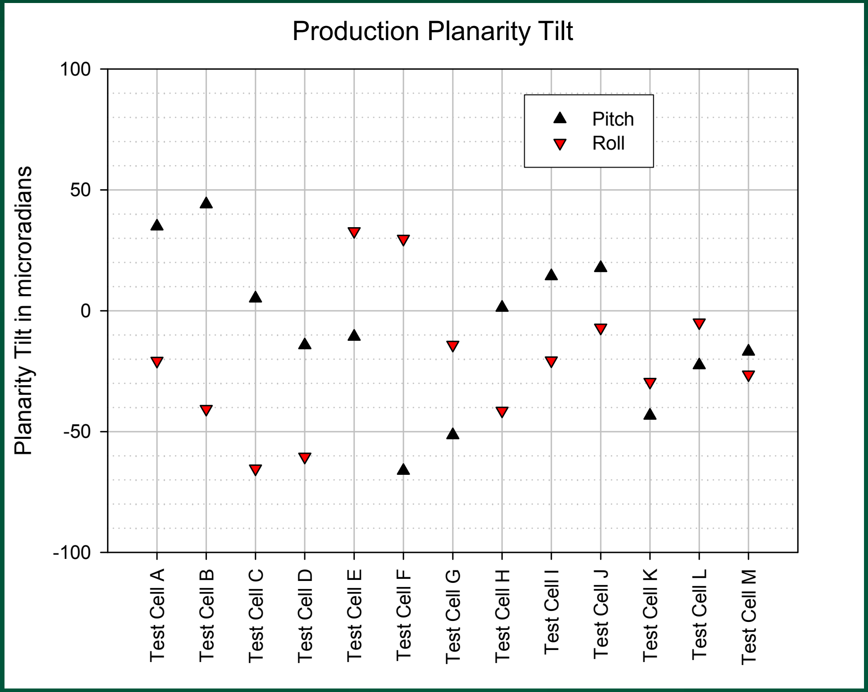
Temperature Dependent Parameters Summary

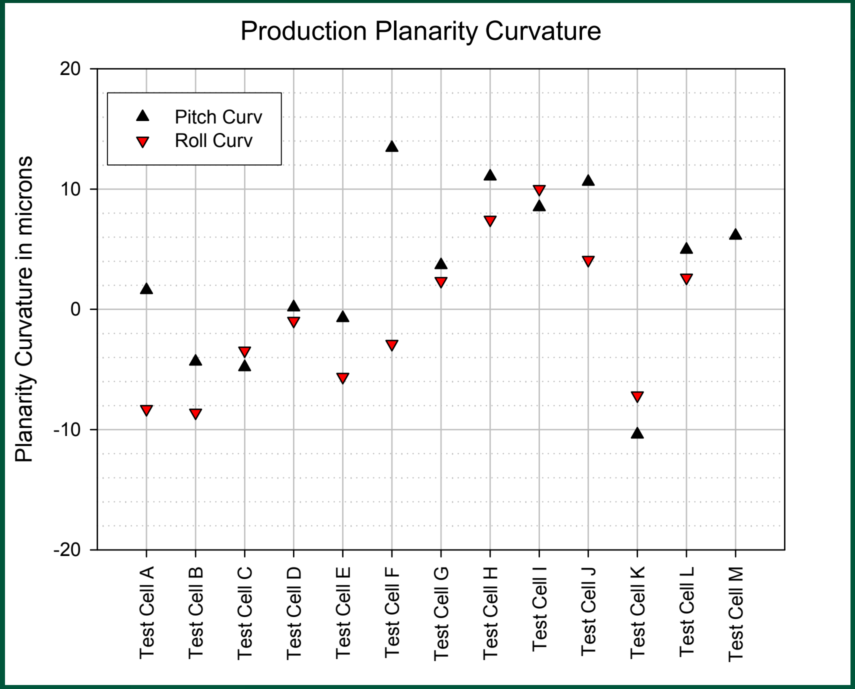
- As bond pad pitch sizes and edge infringement tolerances decrease, the need for thermal characterization becomes more critical.
- The use of Temperature Dependent Parameters can assist in setting new criteria for technology qualifications.
- Micron is pursuing methods to simulate different thermal scenarios within the Metrology tools.

PTPA Database

PTPA Database Introduction

- Script parses all PTPA data logged from probers.
- Code automatically calculates most the parameters discussed in this presentation.

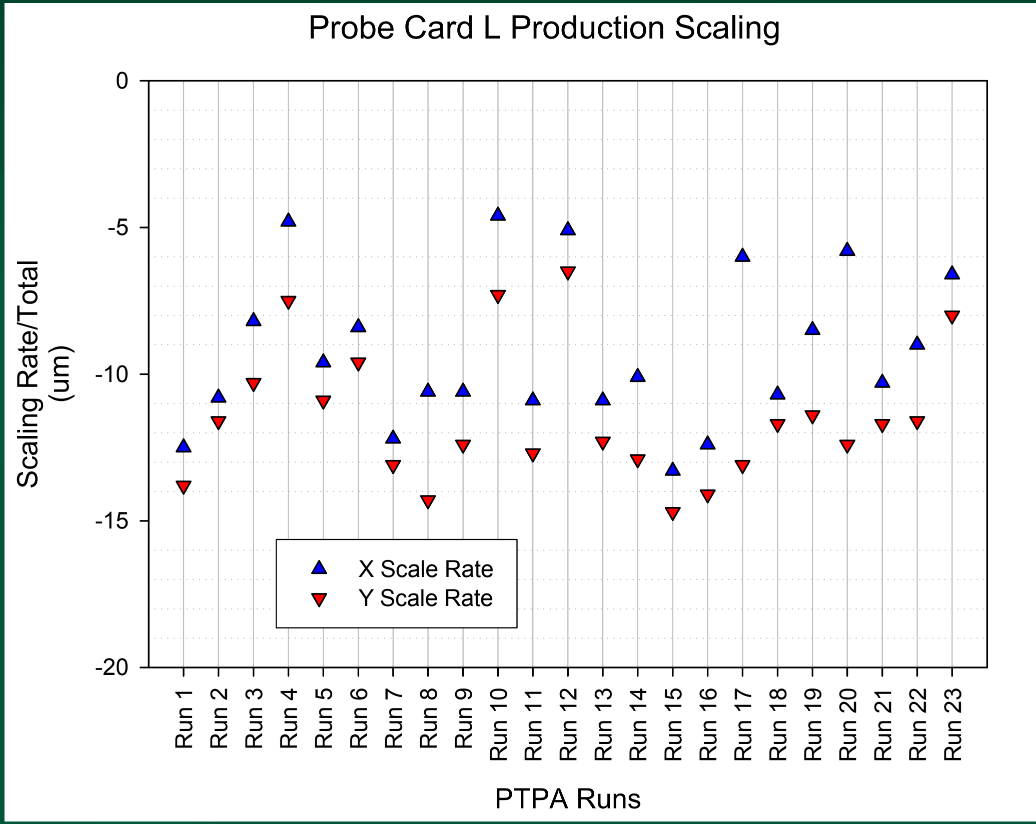




- Snapshot of Planarity is readily available, problems can be readily identified.

PTPA Database-Scaling

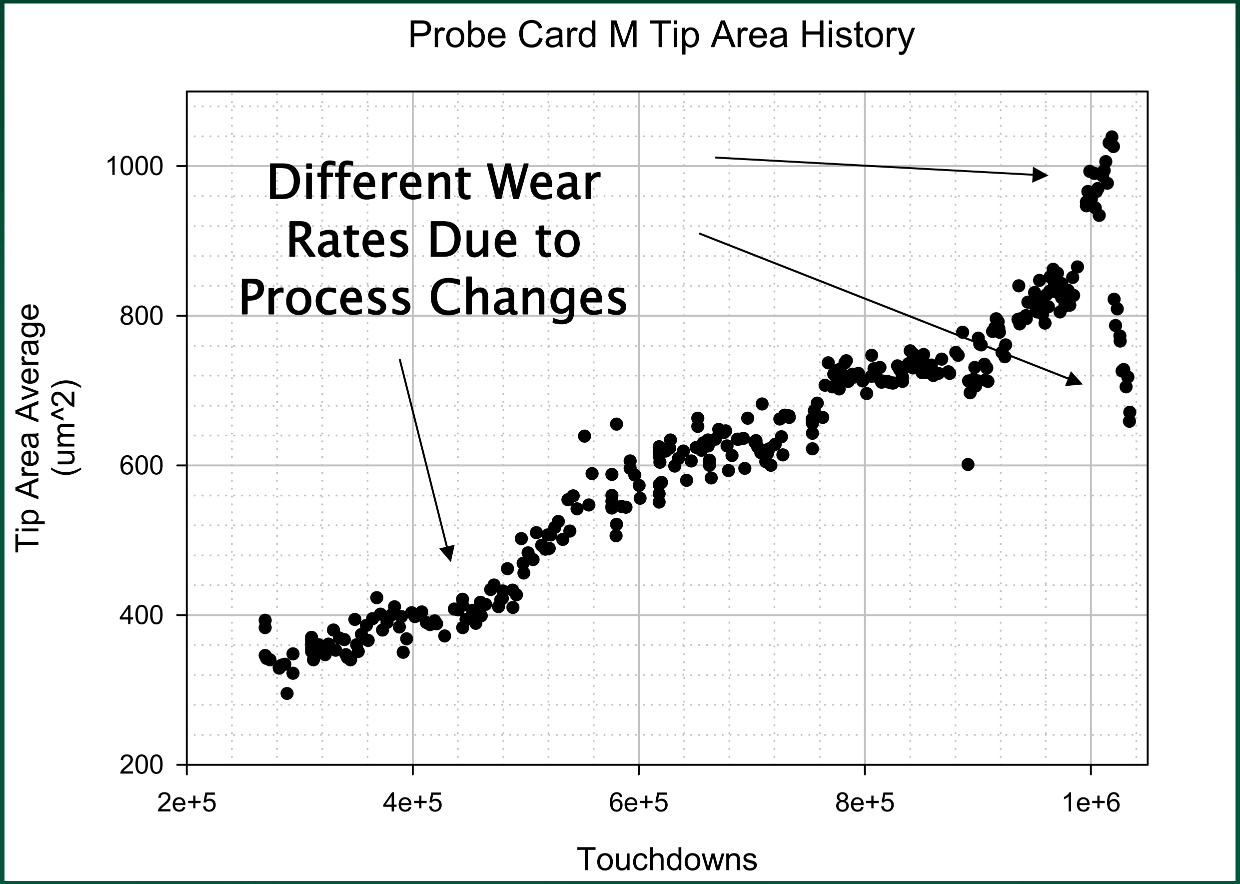
- Scaling may be monitored while Probe Card is in production.



- Probe Card Scaling values change during normal production due to temperature fluctuations within process.

PTPA Database Tip Wear

- Tip wear is monitored in a production environment.



- Process changes can be executed and its effects can be quantified.

Summary

- PTPA data has been an instrumental tool to evaluate and qualify new Probe Card technologies.
- Many Planarity issues were solved thru incorporating Test Cell PTPA data into planar statistical models.
- Thermal issues can be characterized thru the use of Temperature Dependant Parameters.
- Production X and Y Placement Error can be estimated thru Normal Cumulative Distributions.
- PTPA Database allows for parameters to be readily available to users.
- With all this, Probing Quality can be increased and:

Better Quality = Less Defects!!

Acknowledgements

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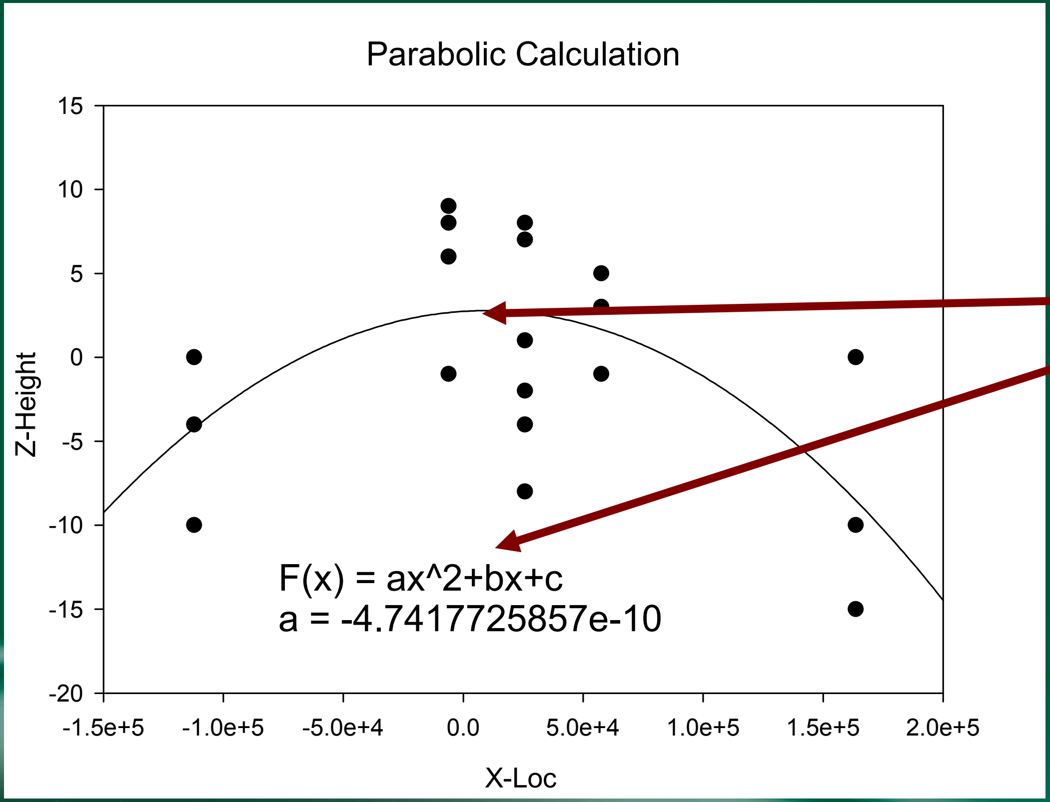
  - Tom Scott
- Micron Technology Idaho QRA
  - Huy Le, Ph.D.

Appendix

Appendix A–Planarity Curvature Formulas

- When defining a best fit quadratic plane, the magnitude of a the parabolic curvature is defined by the x^2 coefficient (a) in:

$$F = \underline{a}x^2 + bx + c$$

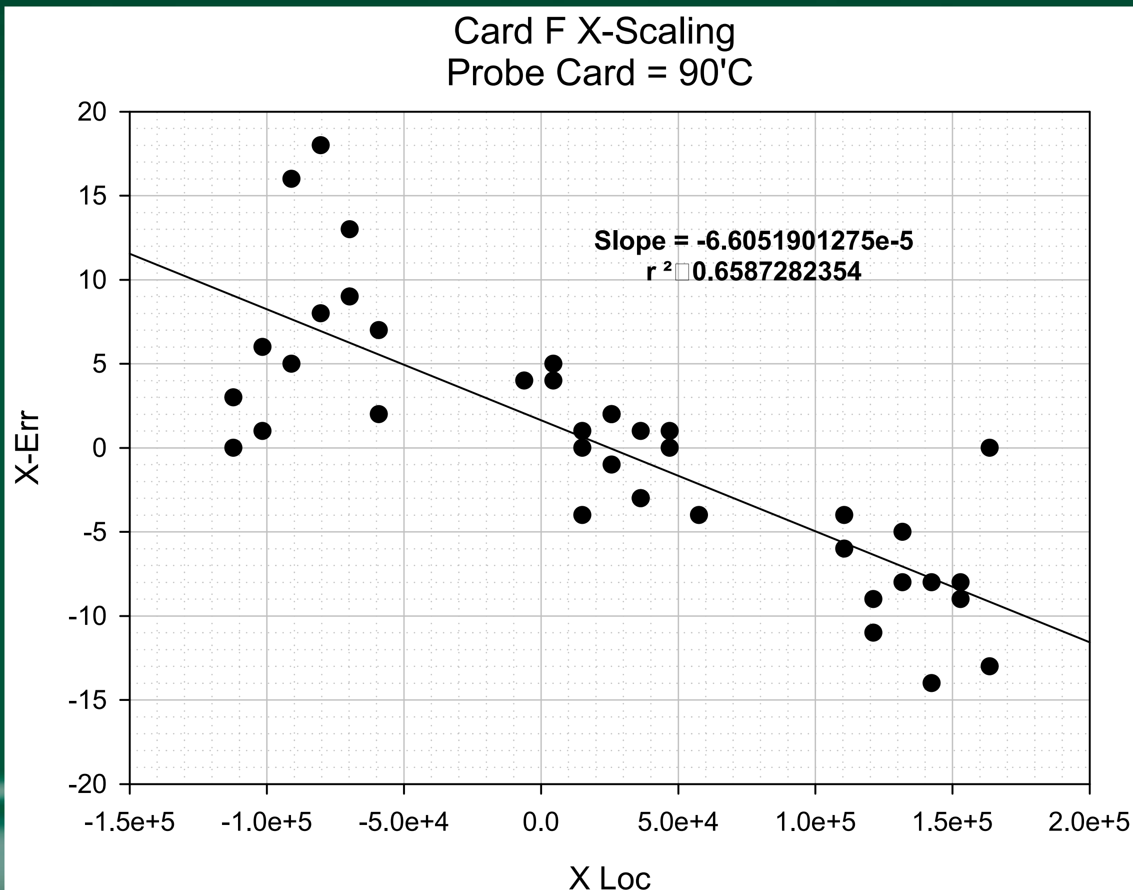


Using known X values (linear dimension of Probe Card), Curvature may be calculated in microns.

Center is the Reference

Appendix B–Scaling Rate

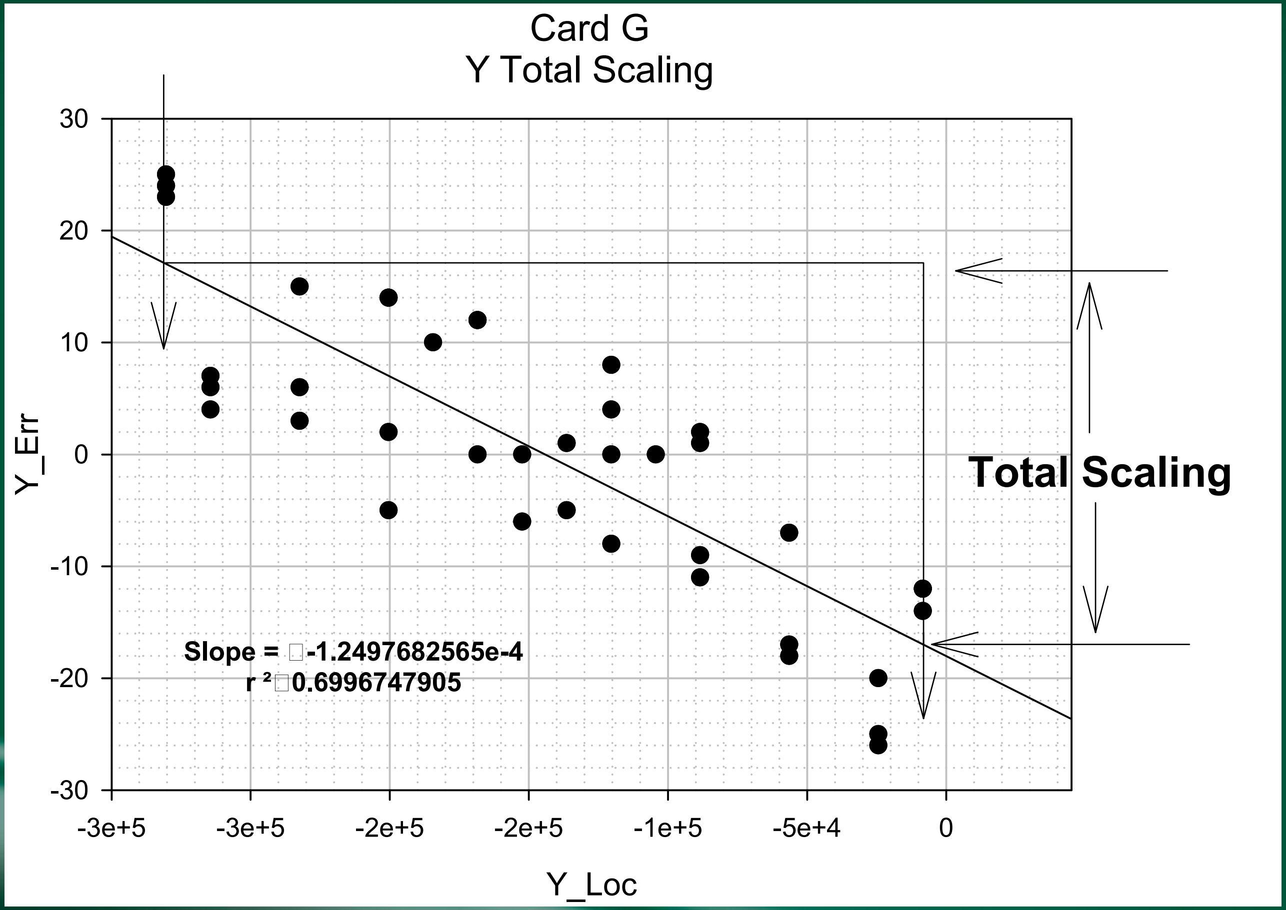
- Scaling Rate may be calculated thru the slope of the regression of the Tip Err over Tip Location distribution.



Scaling Rate can be normalized to conventional unit [CU = um/100mm]
To convert to [um/100mm] = Slope * 100,000
From the graph example [um/100mm] = –6.605e-5 * 100,000 = –6.605um/100mm

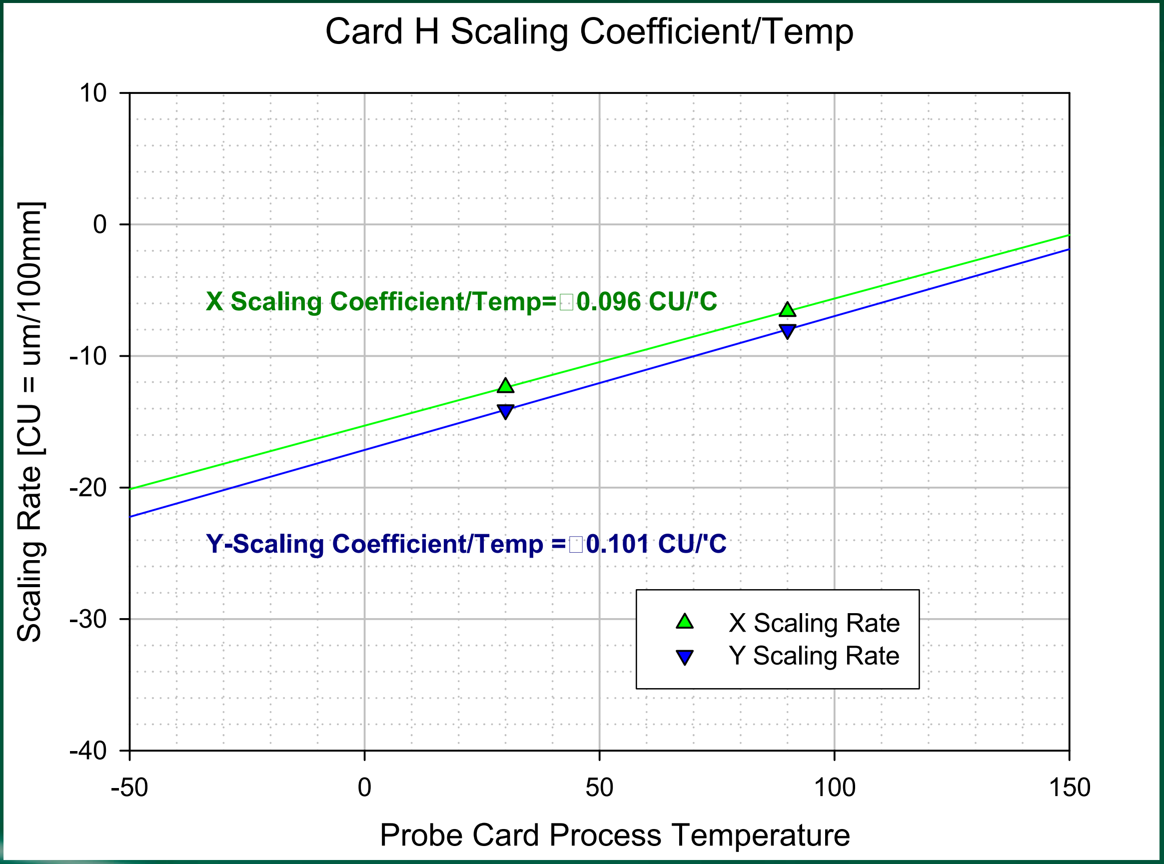
Appendix C–Total Scaling

- Total Scaling may be calculated thru multiplying the slope of the regression of the Tip Err over Tip Location distribution by the total dimension of the Probe Card



Appendix D–Scaling Coefficient/Temperature

- Illustrated Scaling Coefficient/Temperature is defined thru Scaling Rate



- Probe Card will have more optimal Scaling values at higher temperatures, vendor may need to apply a Scaling Offset

Appendix E – Normal Cumulative Distributions

- Normal Cumulative Distributions take into account:
  - The Average of the sample
    - For X_Err and Y_Err, should be close to zero
  - The Standard Deviation of the sample
  - The Probability Percentile for extrapolation
    - Takes into account the total probe tip count of the Probe Card
- For more information:

  http://www.itl.nist.gov/div898/handbook/eda/section3/eda3661.htm