AppliedPrecision

Closing the Loop:

Incorporation of Sort Floor Data to Improve Probe Card Performance

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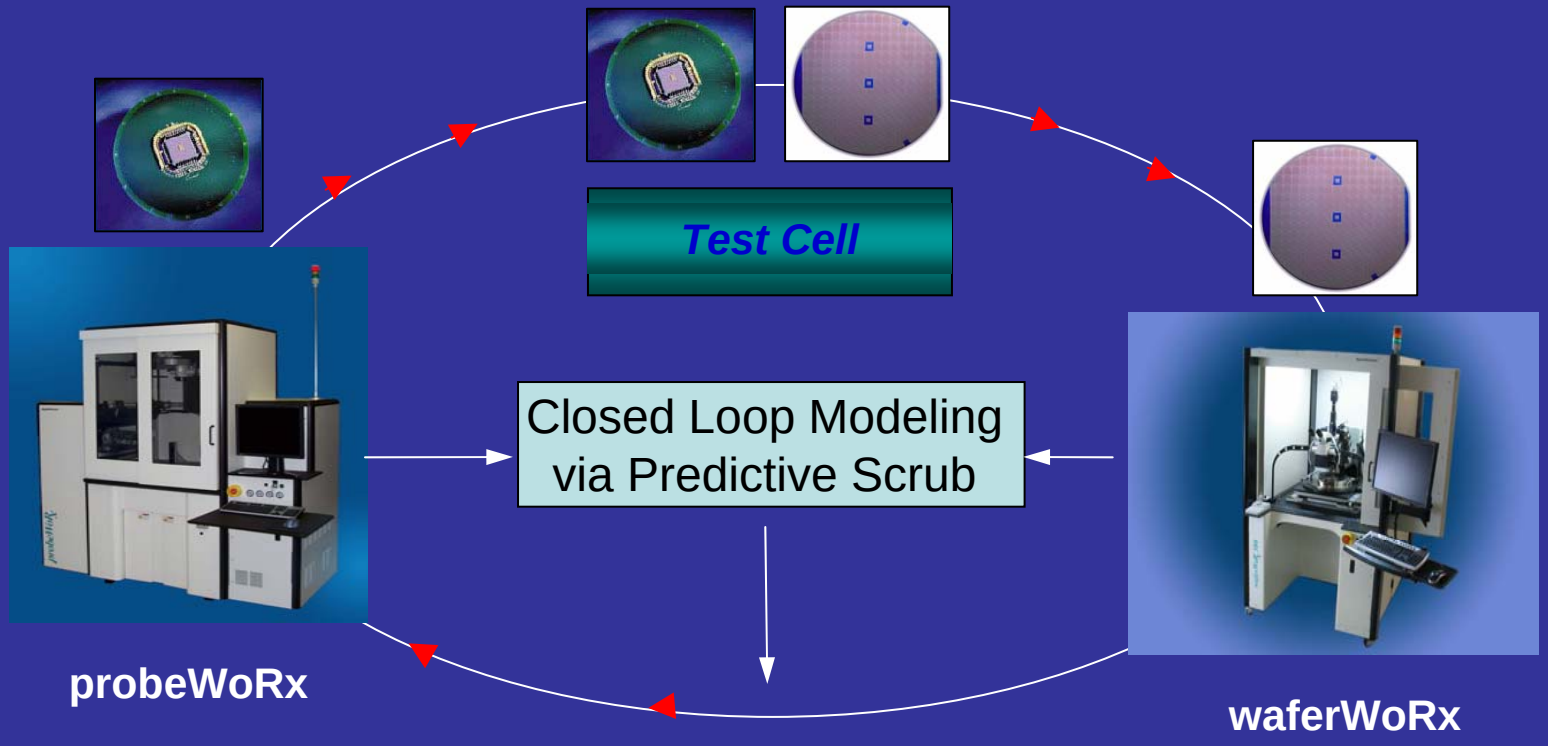
What is the best method to optimize the performance of the probe card in the test cell?

- Cannot directly measure probe card performance within the test cell
  - The wafer is not transparent
  - Probe Card Analyzer (PCA) qualifies probe card prior to wafer test
  - Probe Mark Analyzer (PMA) quantifies the probe card performance post probe via scrub mark analysis
- PCA and Test Cell environments are inherently different
  - Friction
  - Overtravel differences (Deflection, Test Interface)
  - Temperature differences

Introducing a Closed Loop Probing Process

Closing the Loop



- **Build Closed Loop Model**
  - Measure probe card on a PCA
  - Probe wafers in the test cell
  - Measure the probe card performance at test with PMA
  - Analyze PCA and PMA data to build Closed Loop Model
- **Apply Closed Loop Model in PCA to deliver optimized probe cards to the test cell via predicted probe card measurements**

Scrub Measurement Correlation

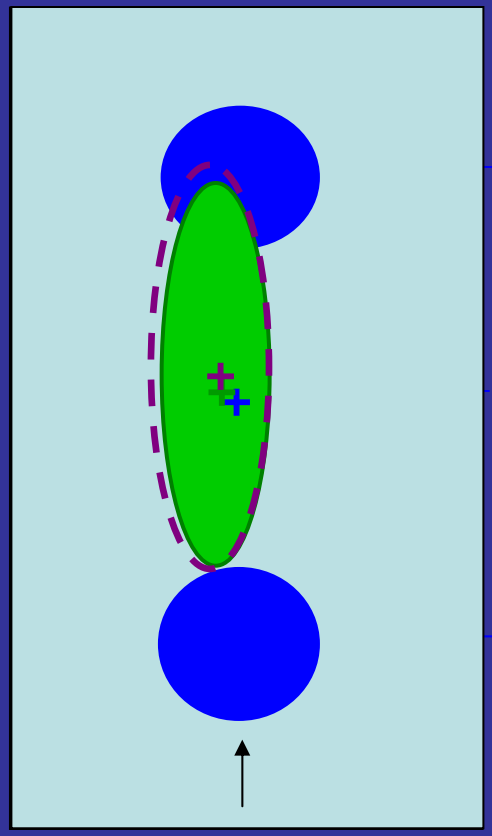
Closing the Loop

1) PCA Measurement

2) Quantify PCA differences with Test Cell

3) Develop Closed Loop Model

4) Implement Predictive Scrub with PCA



Overtravel Position (OT)

Center Position

No Overtravel Position (NOT)

PCA measurement

waferWoRx measurement

Predicted Scrub

The Design of Experiment

Validate Closed Loop Metrology improvements across a range of conditions

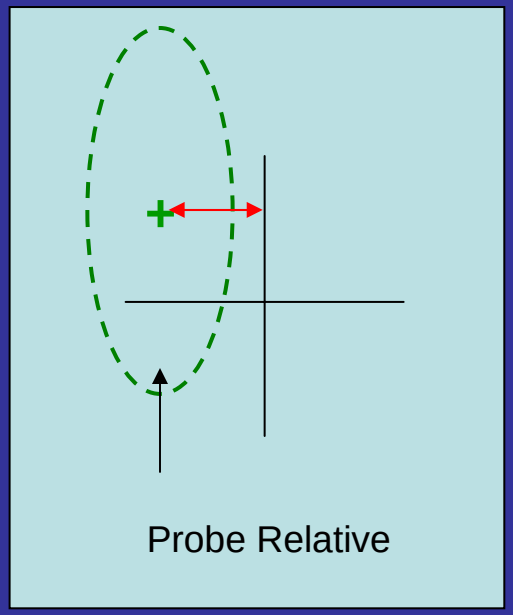
- Various probe card technologies
- Different tester types & different probers
- Temperature range (cold, ambient, hot)

Test Procedure

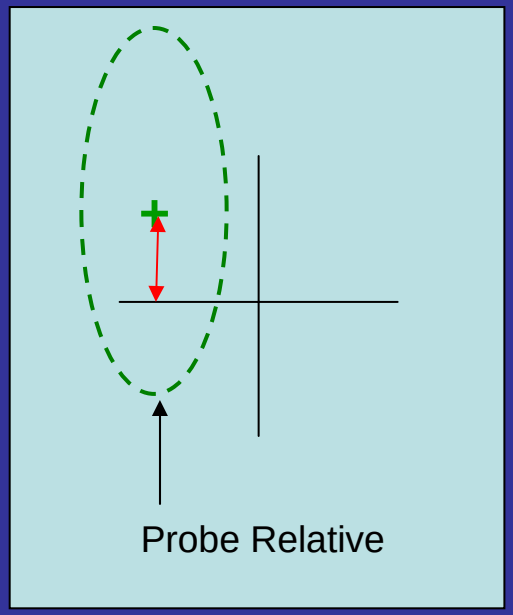
- Run Planarity & Alignment on PCA
- Probe wafer at ambient
- Probe wafer at temperature
- Run scrub mark analysis with PMA
- PCA and PMA data analysis to create predictive scrub model
- Apply predictive scrub model to enhance wafer scrub results

Terminology

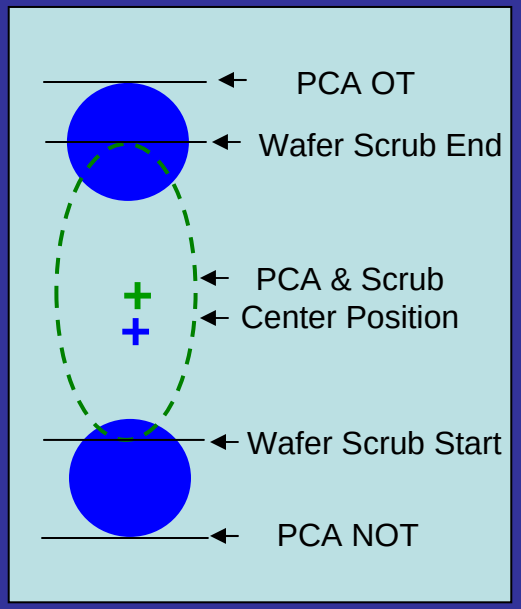
Perpendicular Position



Parallel Position



Measurement Positions



Perpendicular Position:
PCA vs. Wafer Scrub correlation

Sensitive to
- Temperature

Insensitive to
- Overtravel Accuracy
- Friction of surface
- Wafer Scrub mechanics
- Probe tip size

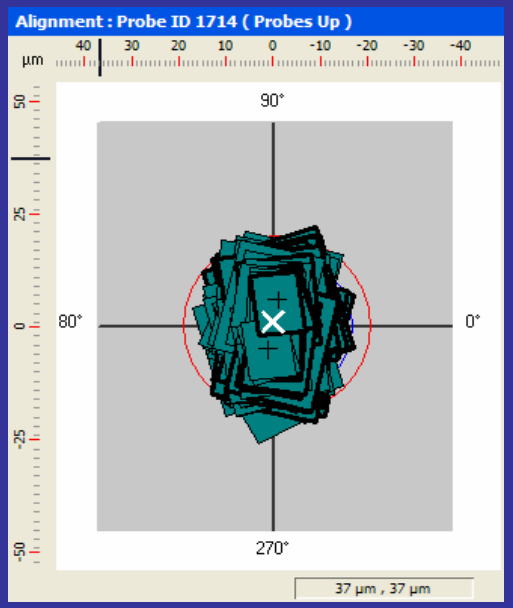
Parallel Position:
PCA vs. Wafer Scrub correlation

Sensitive to
- Temperature
- Overtravel Accuracy
- Friction of surface
- Wafer Scrub mechanics
- Probe tip size
- Tier

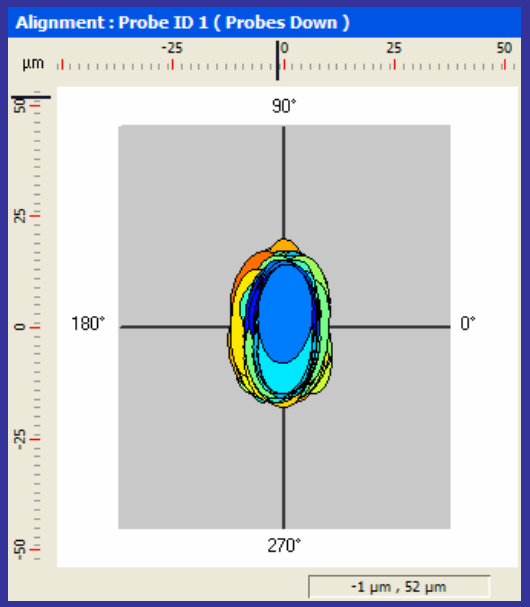
- PCA measurement
- PMA @ Ambient
- PMA @ Temperature
- Predictive Scrub

Scrub Signatures - Case Study #1

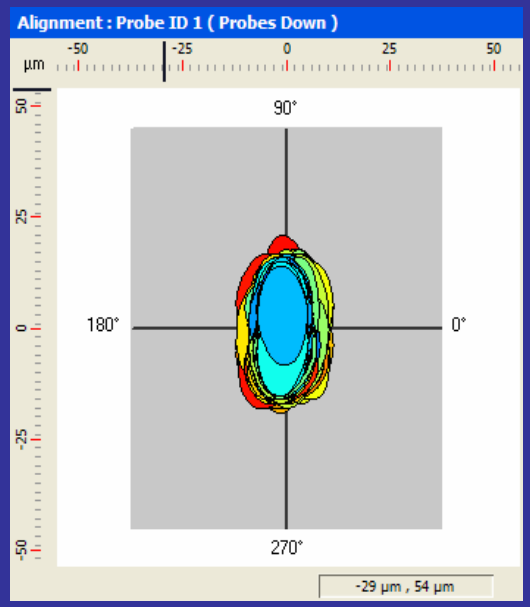
- Superpad display of probes and scrubs
  - Medium size array (< 100mm, ~4000 probes)



PCA
all probes

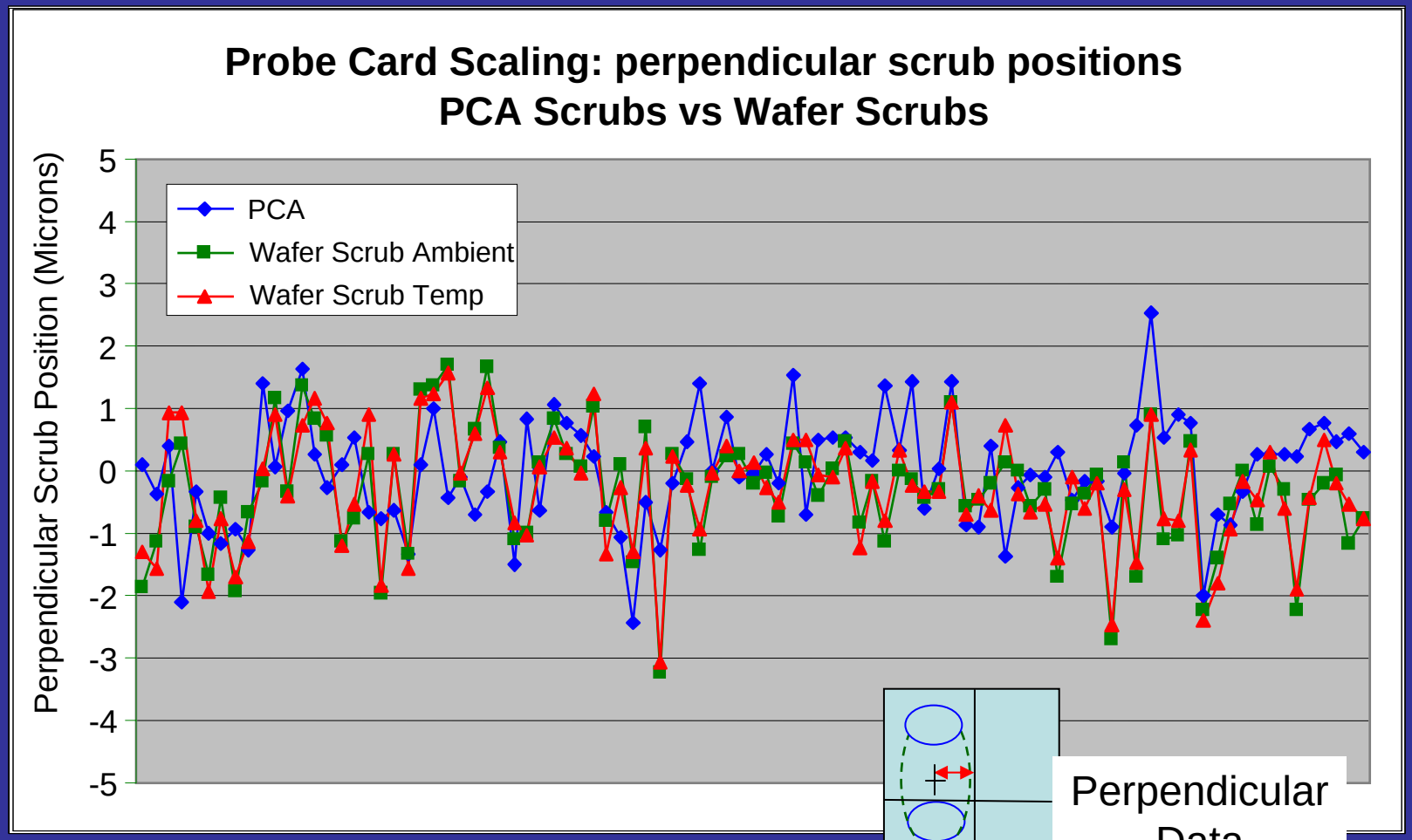


PMA *ambient*
all probes
prober errors removed



PMA *@ temperature*
all probes
prober errors removed

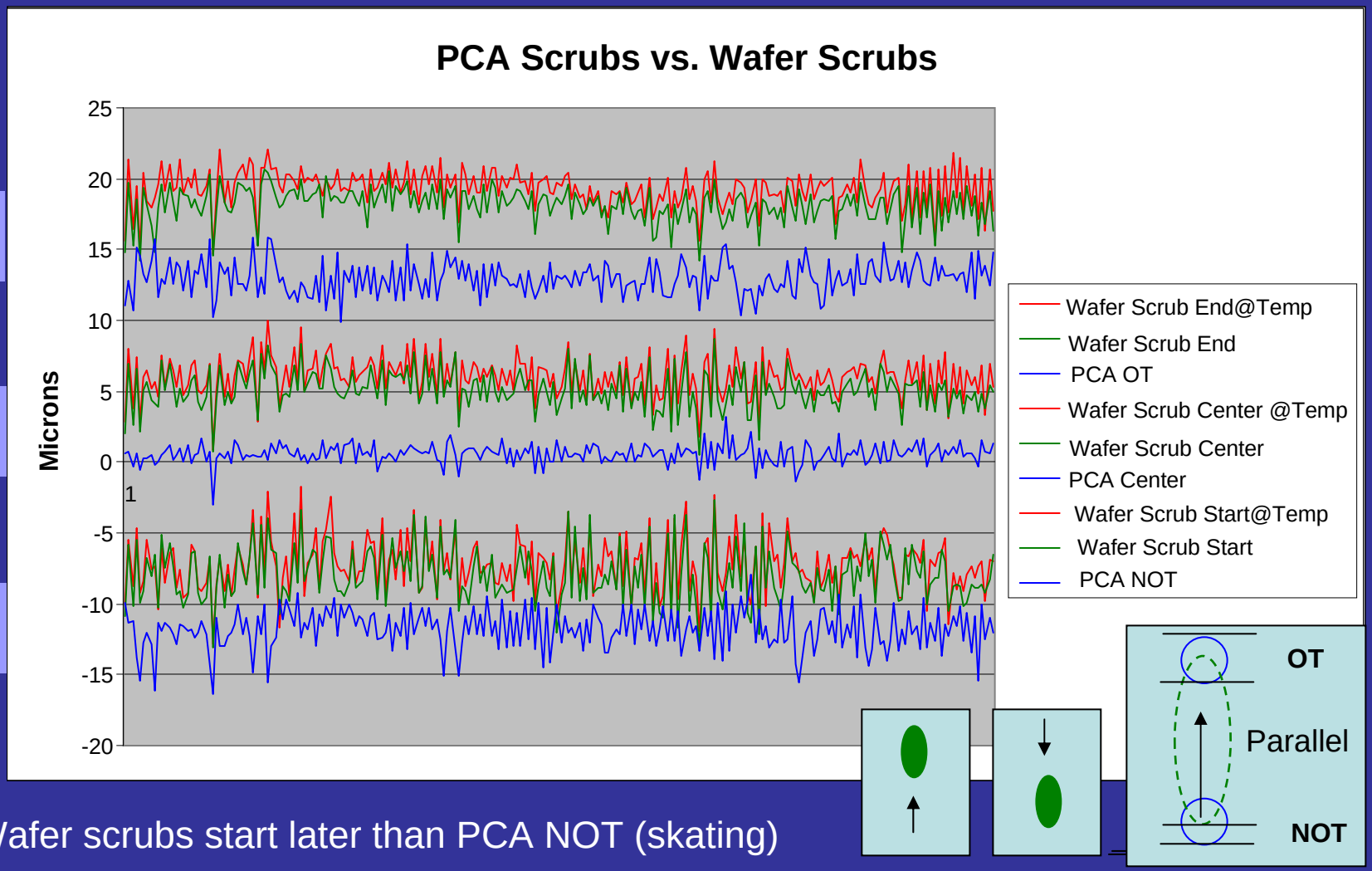
Perpendicular Scrub Data – Case Study #1



- Sample of probes sorted by X position
- Wafer scrubs at ambient and temperature have minimal scaling effects
- Good correlation between PCA and wafer scrubs: 2.1 microns @ 3 sigma

Parallel Scrub Data – Case Study #1

Closing the Loop



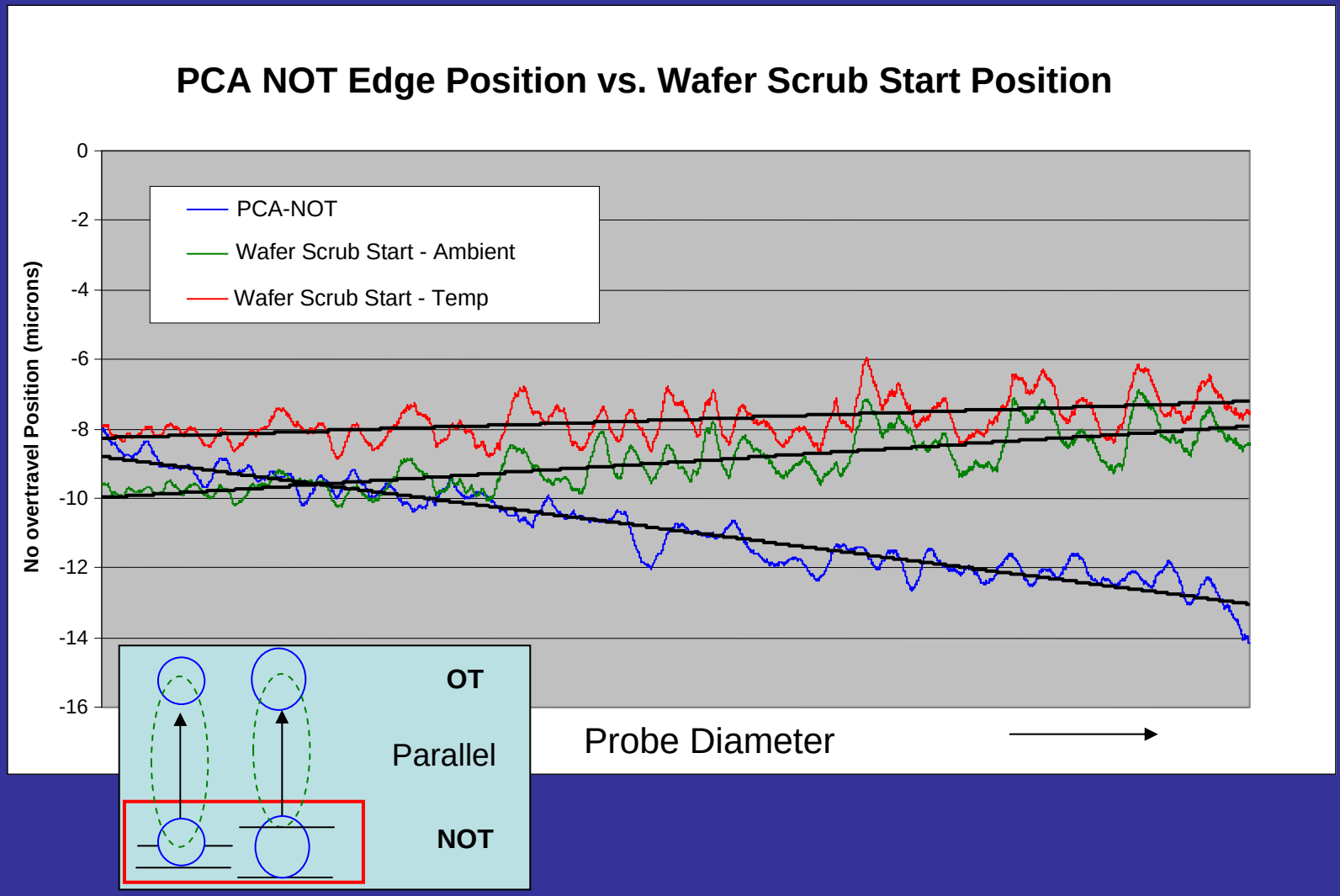
Over Travel

Center Scrub

No Overtravel

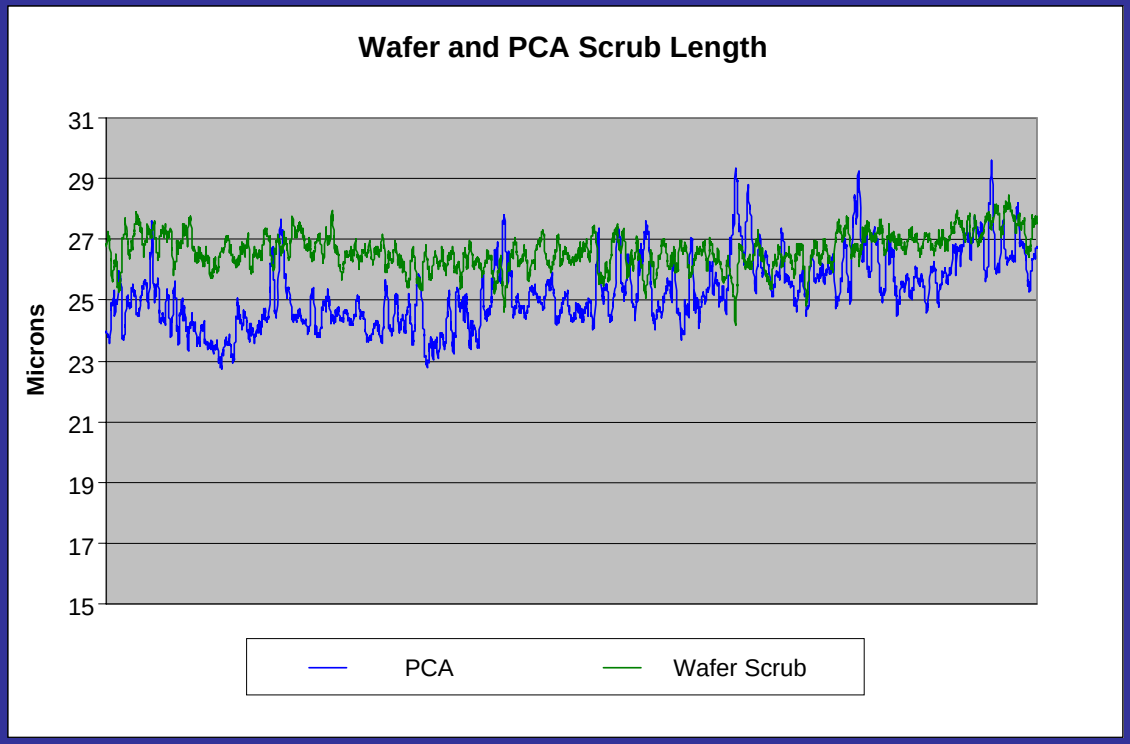
- Wafer scrubs start later than PCA NOT (skating)
- Wafer scrub end positions are farther than PCA OT (scrub length)
- Overall scrub length is the same (indicates OT differential between PCA & test cell)
- Center position correlation: 7.2 micron @ 3 sigma

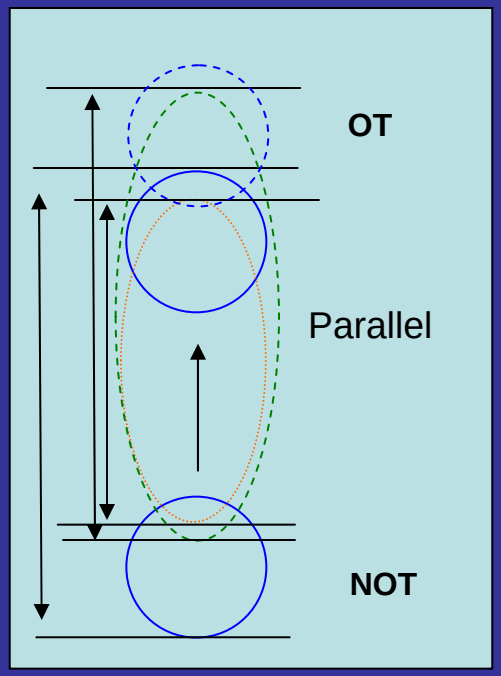
NOT Position Data – Case Study #1



- PCA Scrub signature starts “earlier” the larger the probe diameter
- Wafer Scrub signature begins “later” the larger the probe diameter

Overtravel Differential – Case Study #1





- Wafer and PCA scrub lengths are roughly equal
- Expect wafer scrubs to be shorter than PCA due to skating
- Therefore OT on the test cell is larger than OT on the PCA

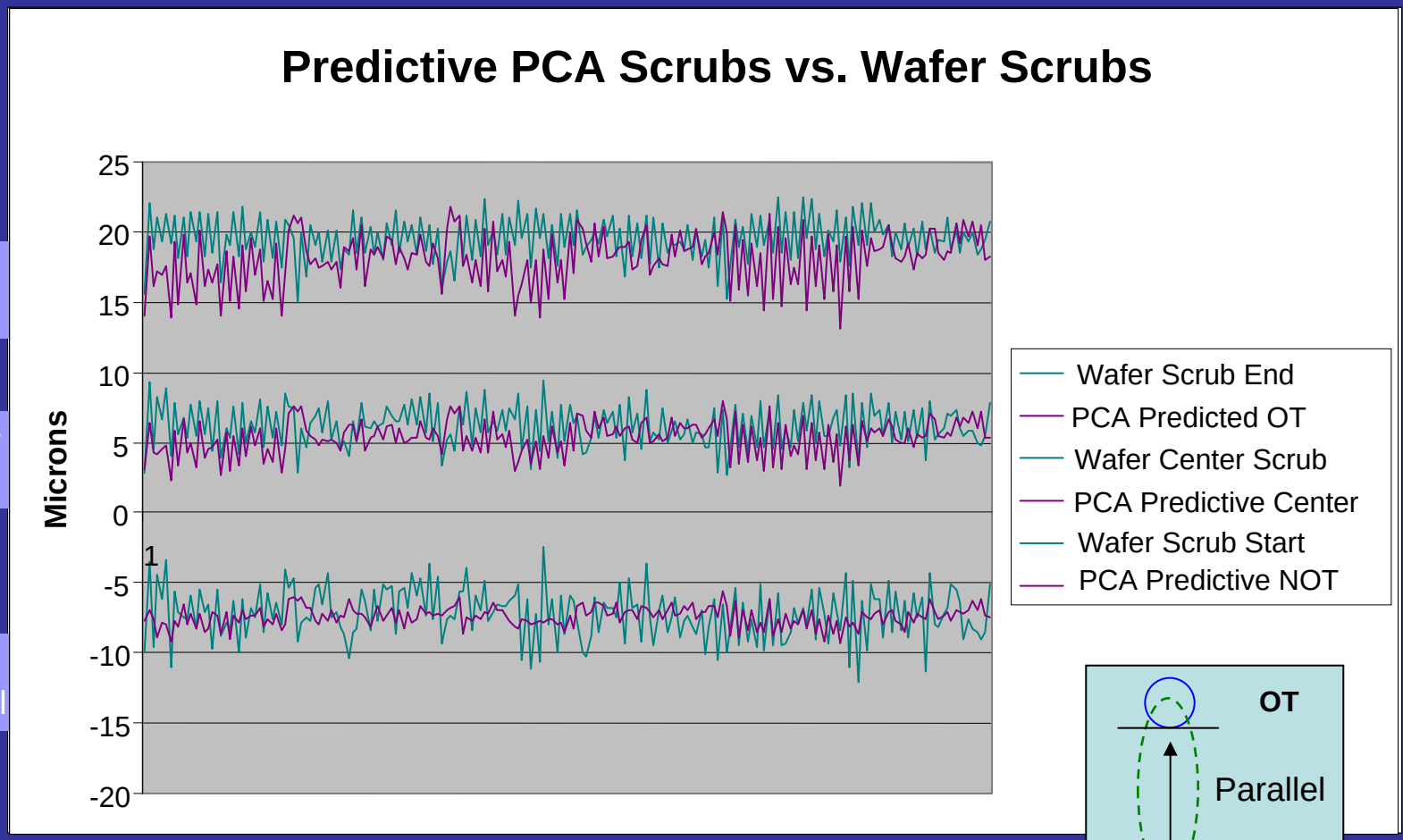
Closed Loop Model Results: Case Study #1

Closing the Loop

Over Travel

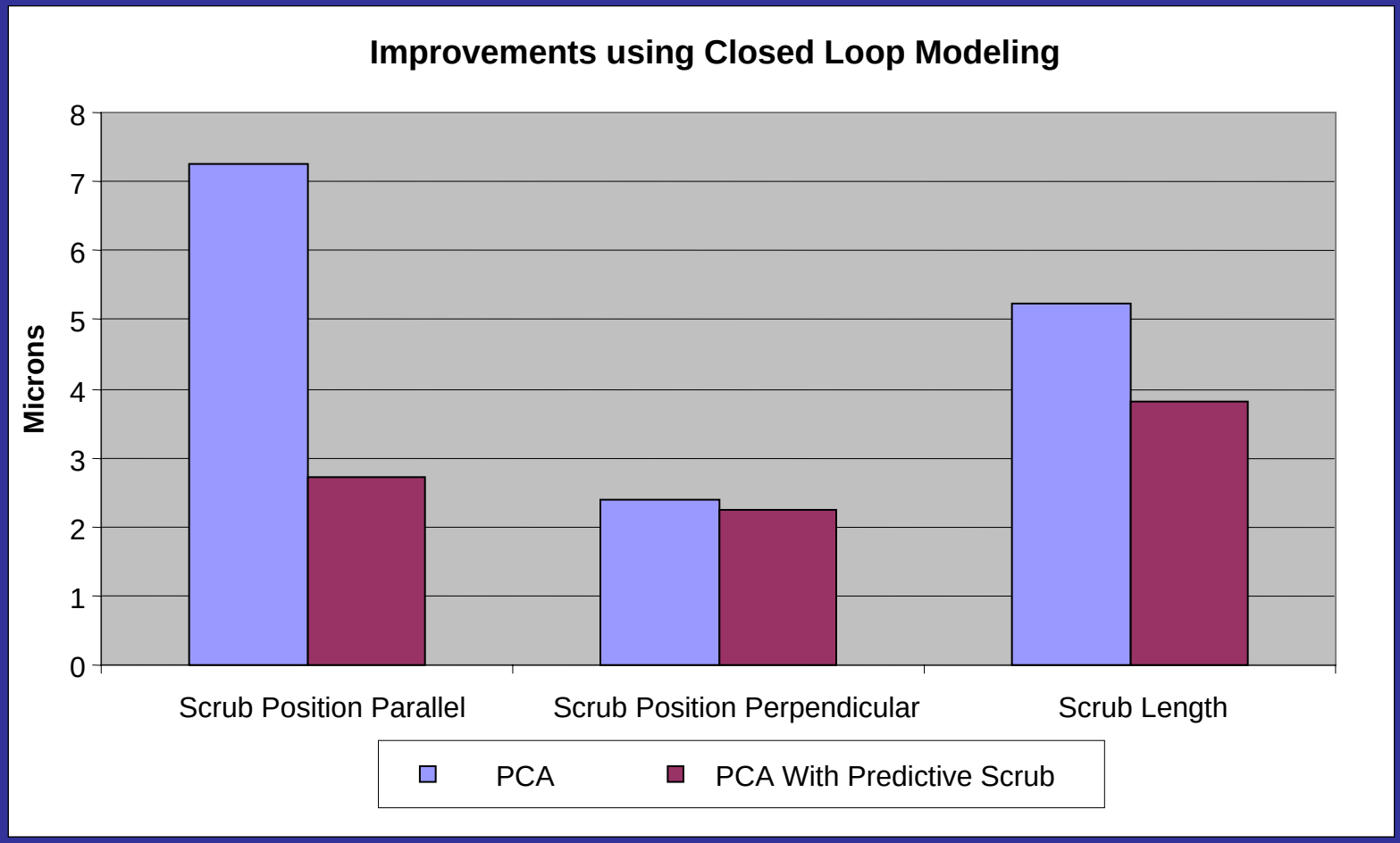
Center Scrub

No Overtravel



- Predictive scrub measurements corrected skating effects and OT differential
- Predicted Scrub Position correlation: 2.6 microns
- Predicted Scrub Length correlation: 3.7 microns

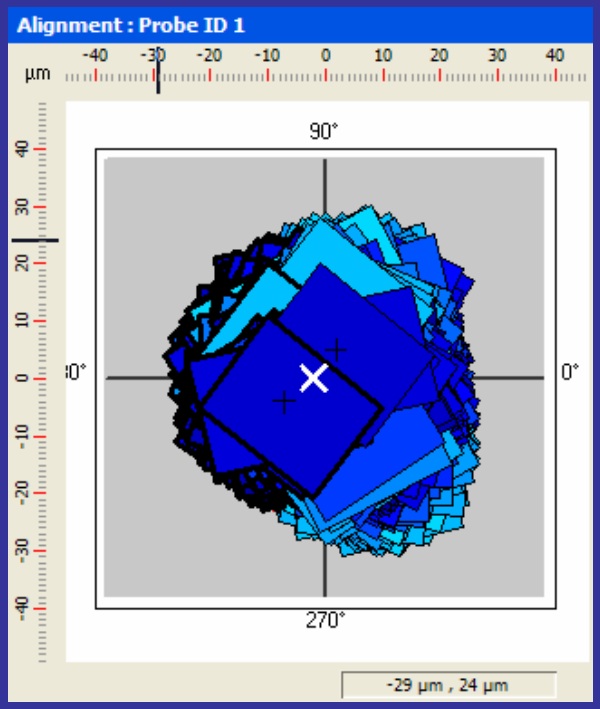
Closed Loop Model Results: Case Study #1



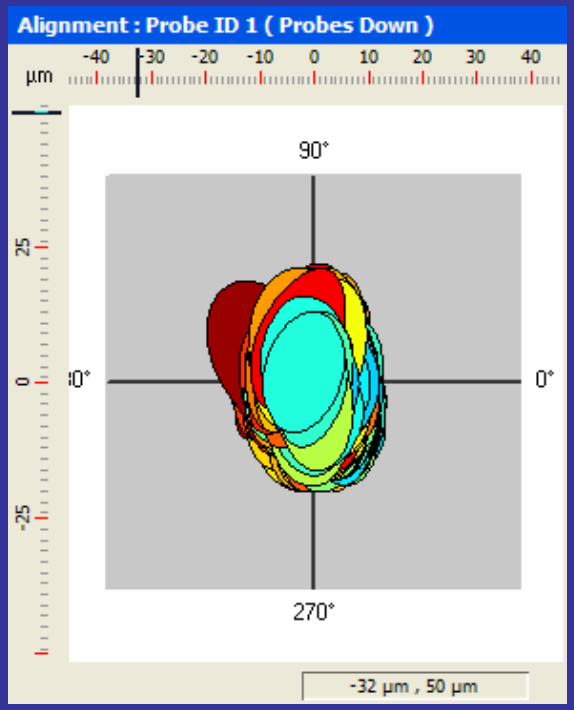
- Closed Loop Modeling improvements
  - 2.7X improvement in Scrub Position predictability
  - 1.4X improvement in Scrub Length predictability

Scrub Signatures - Case Study #2

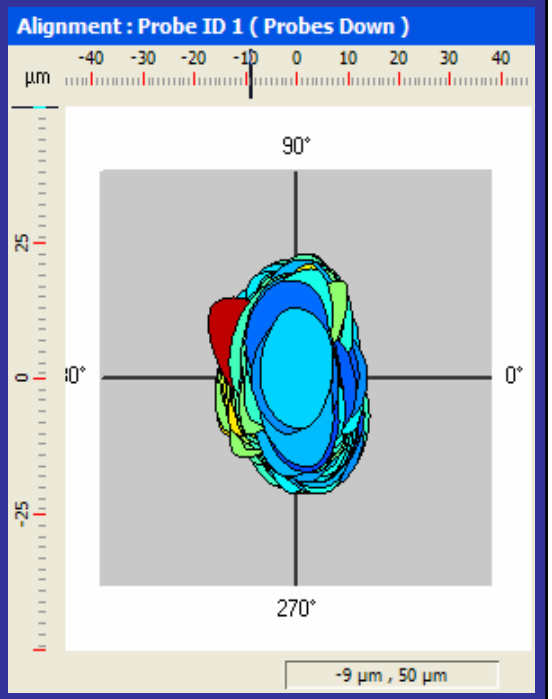
Closing the Loop



PCA – all probes



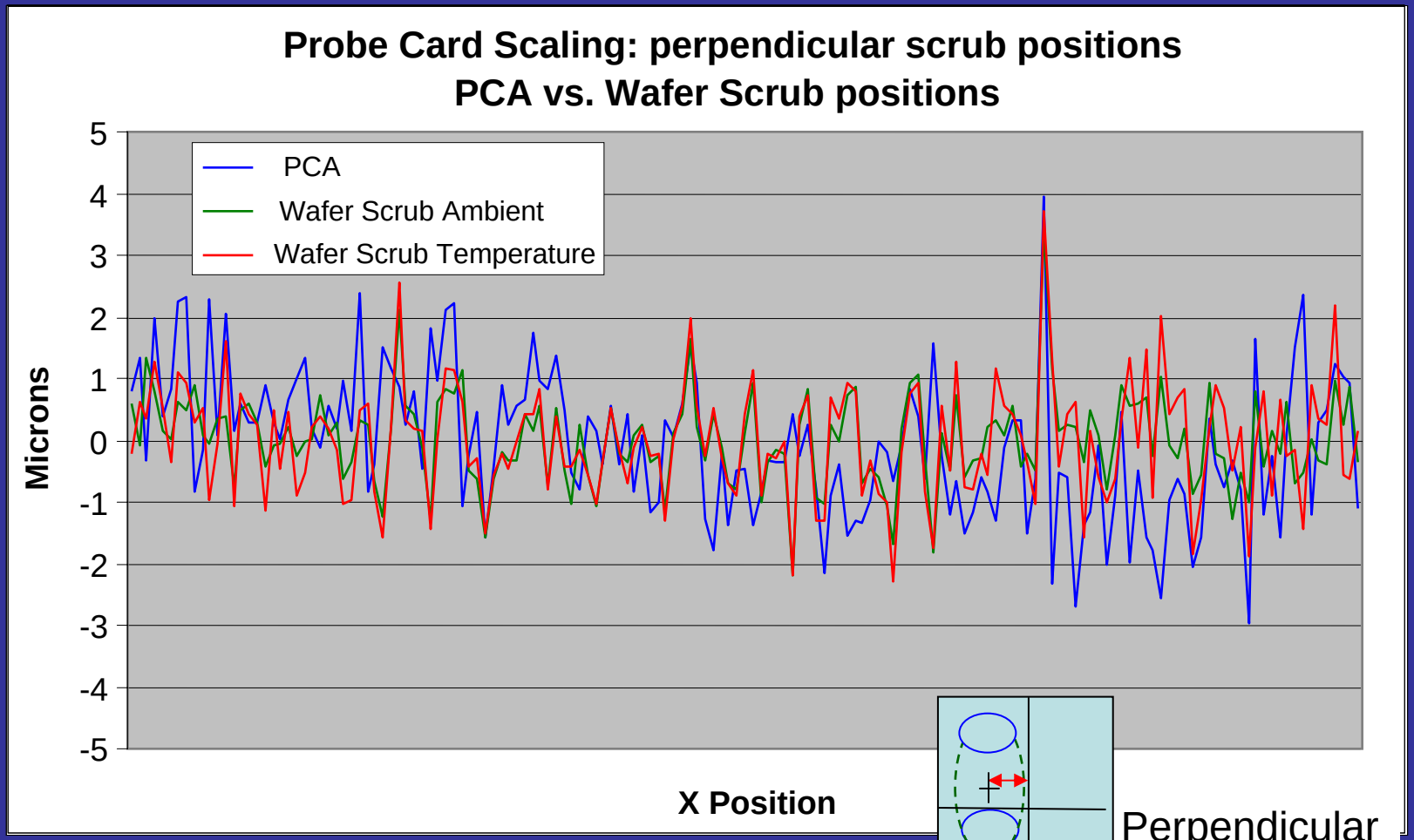
PMA @ ambient
All probe scrubs w/prober errors removed



PMA @ temp
All probe scrubs w/prober errors removed

- Medium size array (< 100mm, ~4000 probes)
- PCA scrub signature is larger than wafer scrub signature
- Ambient and Temperature wafer scrub signatures are very similar

Perpendicular Scrub Data – Case Study #2



Perpendicular Data

- Sample of probes sorted by X position
- Wafer scrubs at ambient and temp have minimal scaling effects
- Good correlation between PCA and wafer scrubs: 2.2 microns @ 3 sigma

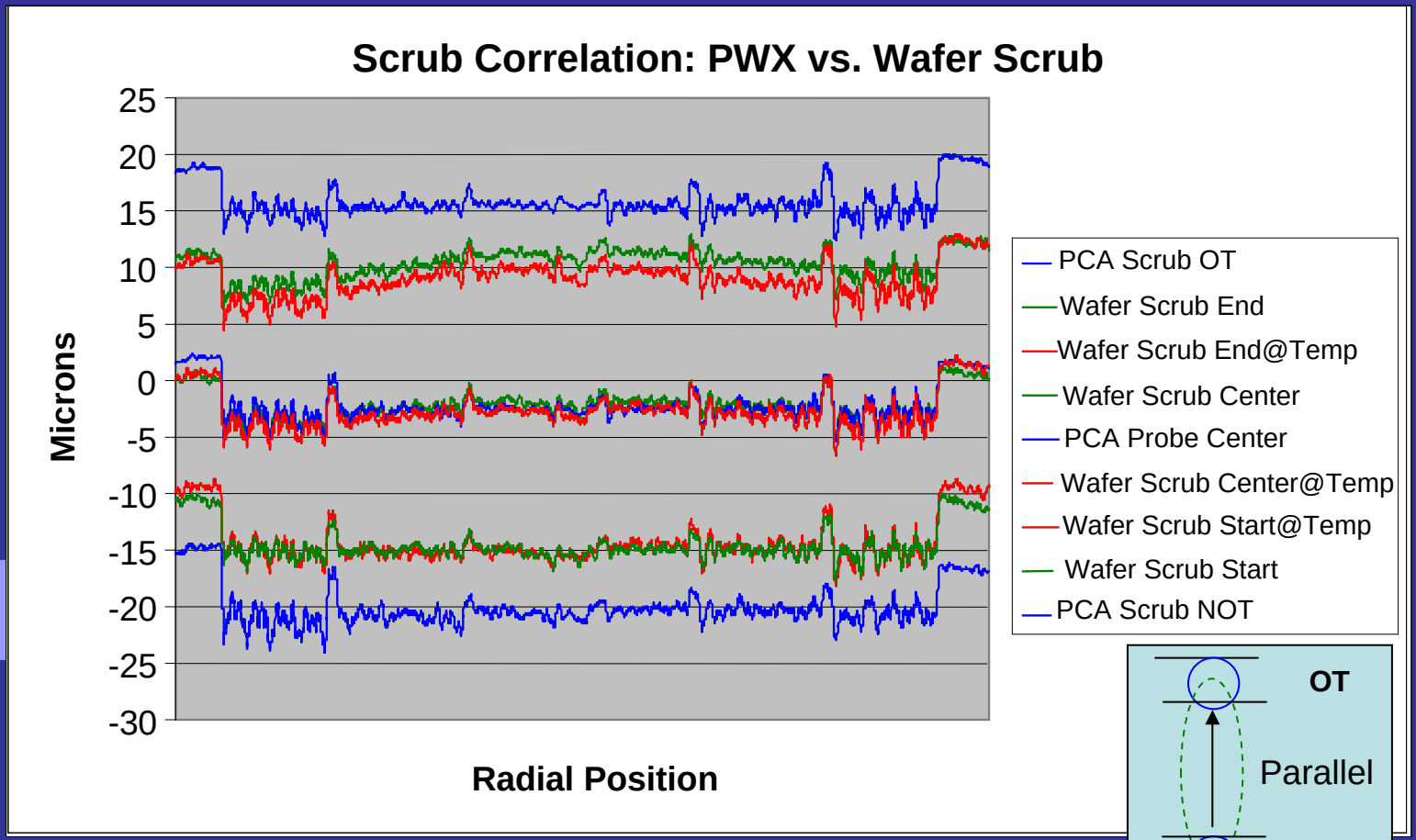
Parallel Scrub Data – Case Study #2

Closing the Loop

Over Travel

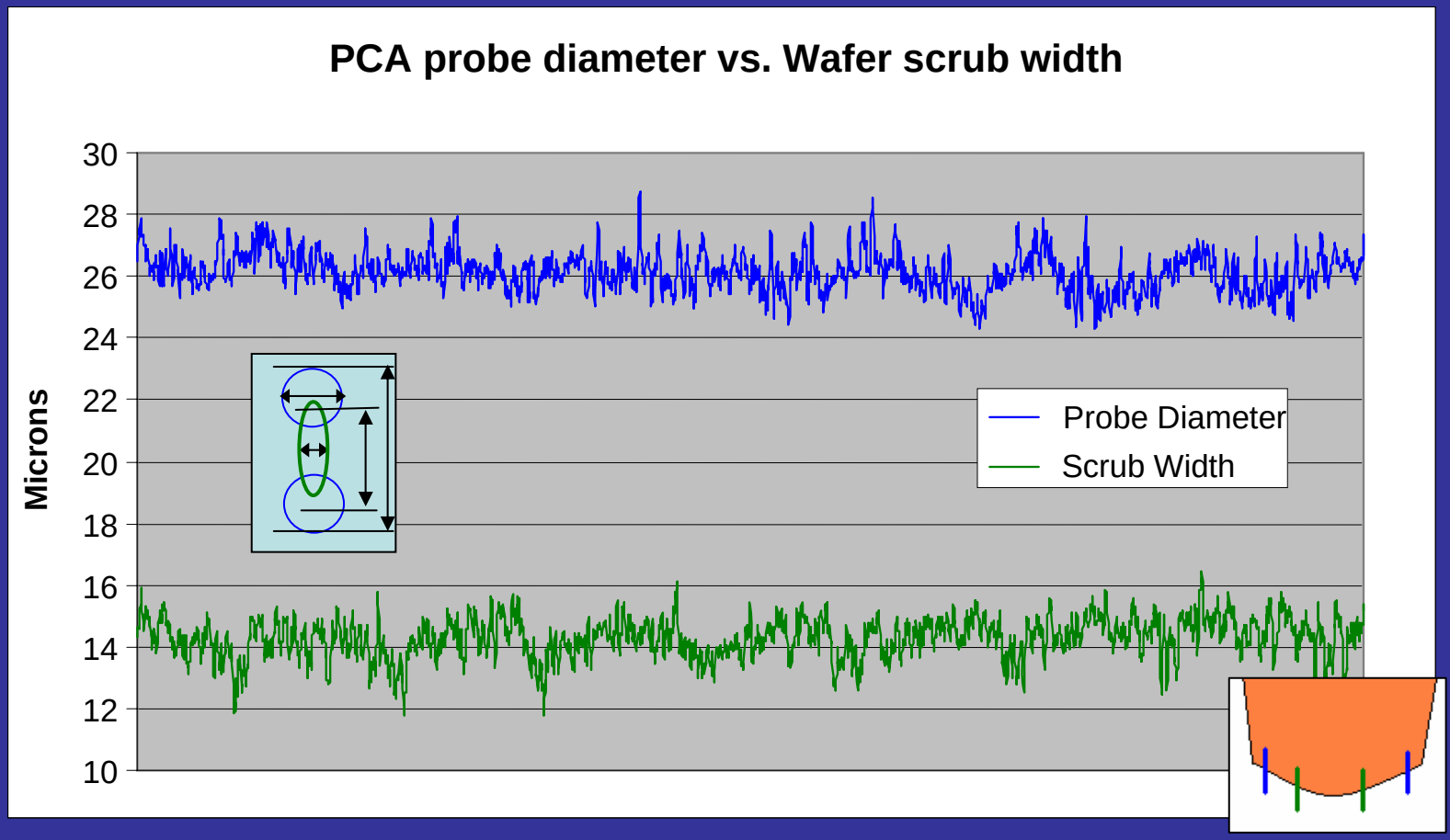
Center Scrub

No Overtravel



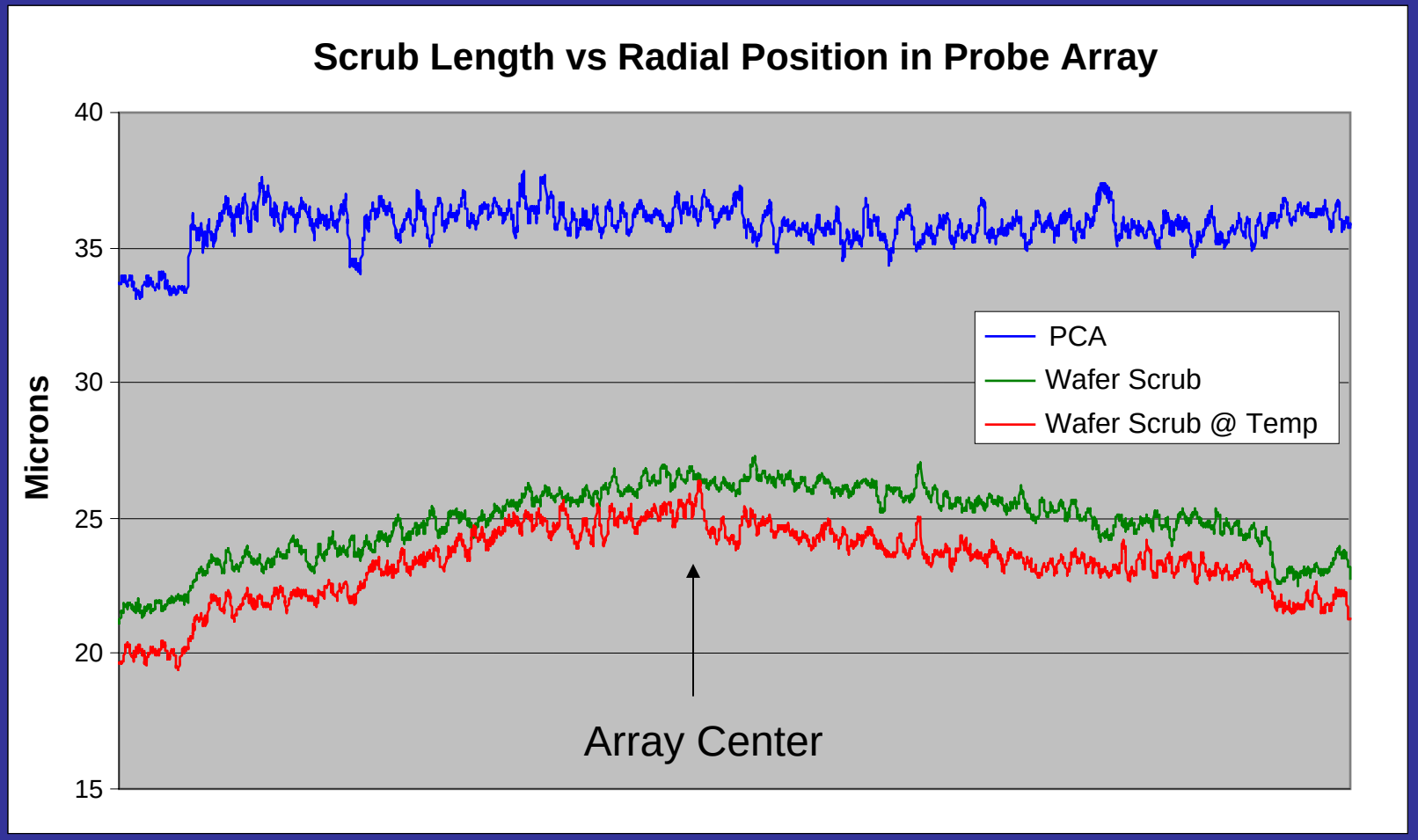
- Probes sorted by probe distance to center of array
- Wafer and PCA Scrub Centers correlate to 2.5 microns @ 3 sigma
- Wafer Scrub Lengths are significantly shorter (11 microns)
- Wafer Scrubs start later by ~ 6 microns
- Wafer Scrub lengths are longer in the middle of the card

Diameter vs. Scrub Width – Case Study #2



- Wafer Scrub <u>width</u> is 12 microns less than the PCA probe diameter
- Shape of probe - PCA optical size vs. Wafer scrub size
- Wafer Scrub <u>length</u> is also 12 microns less than the PCA scrub length

Scrub length vs. Radial Position – Case Study #2



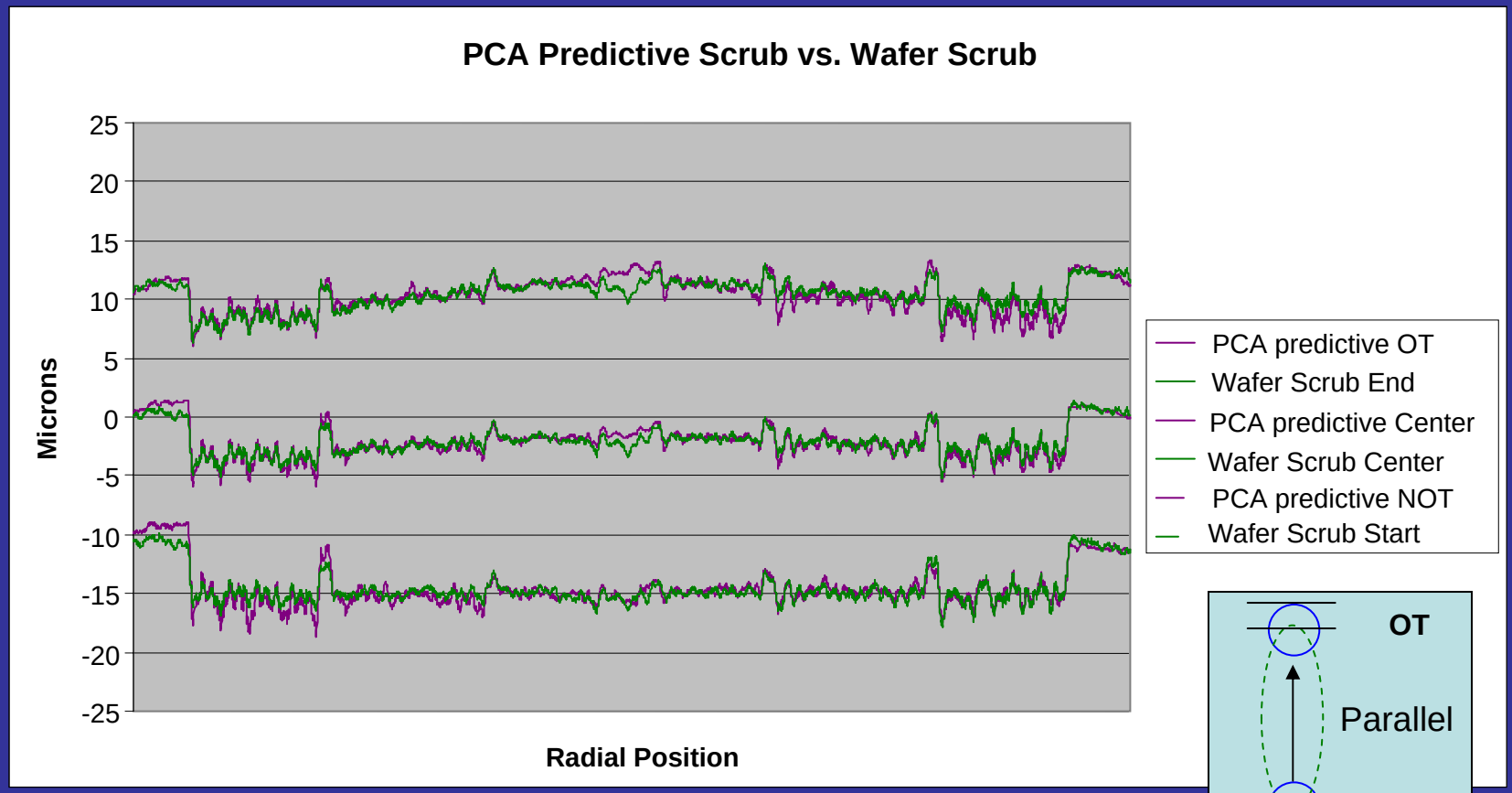
- Probes in the center of the probe card are scrubbing farther on the wafer
- PCA scrub lengths are relatively flat as a function of radius

Closed Loop Model Results – Case Study #2

Over Travel

Center Scrub

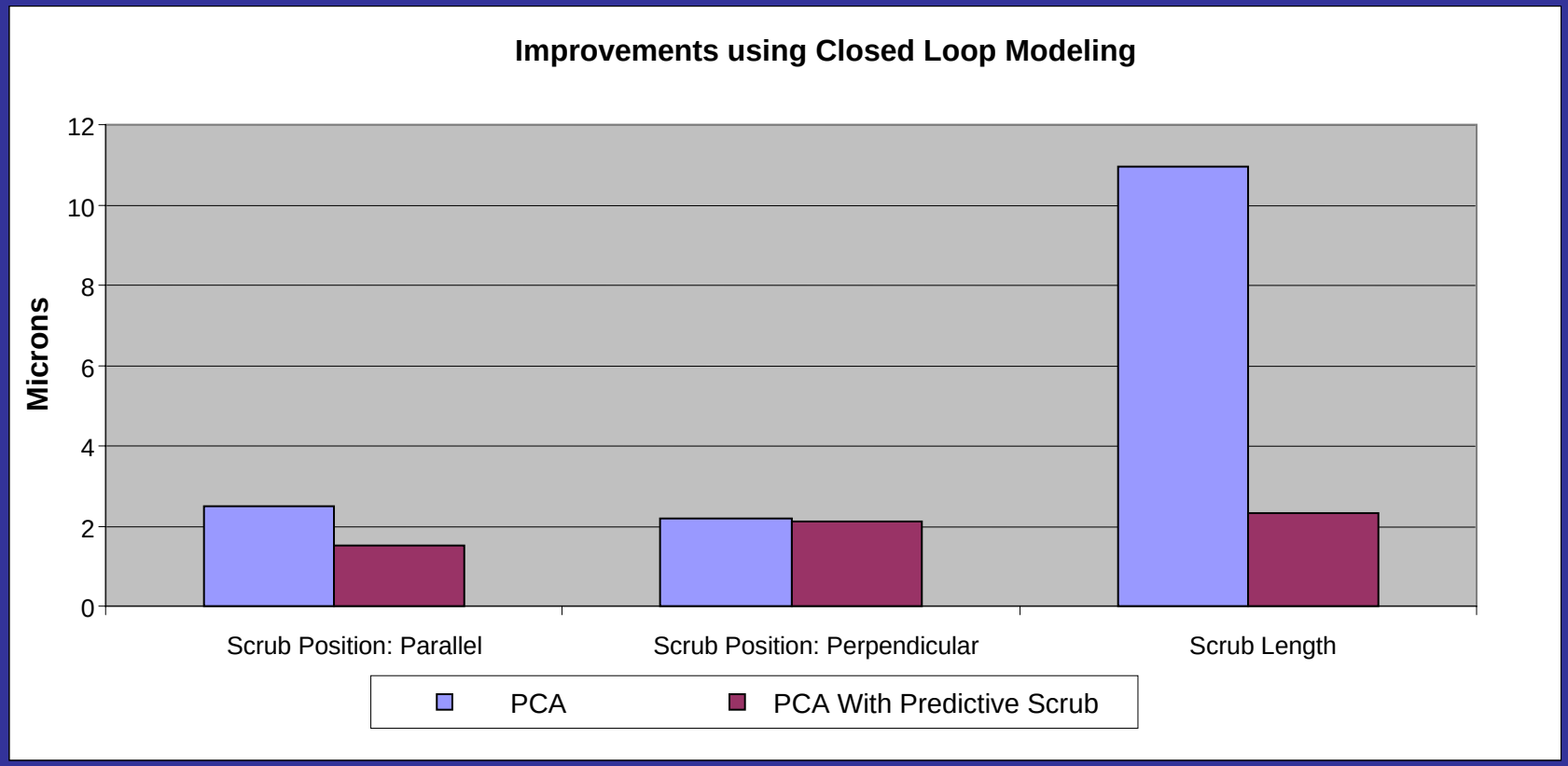
No Overtravel



- Probes sorted by probe radial distance from array center
- Scrub Length correlation = 11 microns @ 3 sigma
- With predictive scrub: Scrub Length correlation = 2.3 microns @ 3 sigma
- With predictive scrub: Scrub Center correlation = 1.5 microns @ 3 sigma

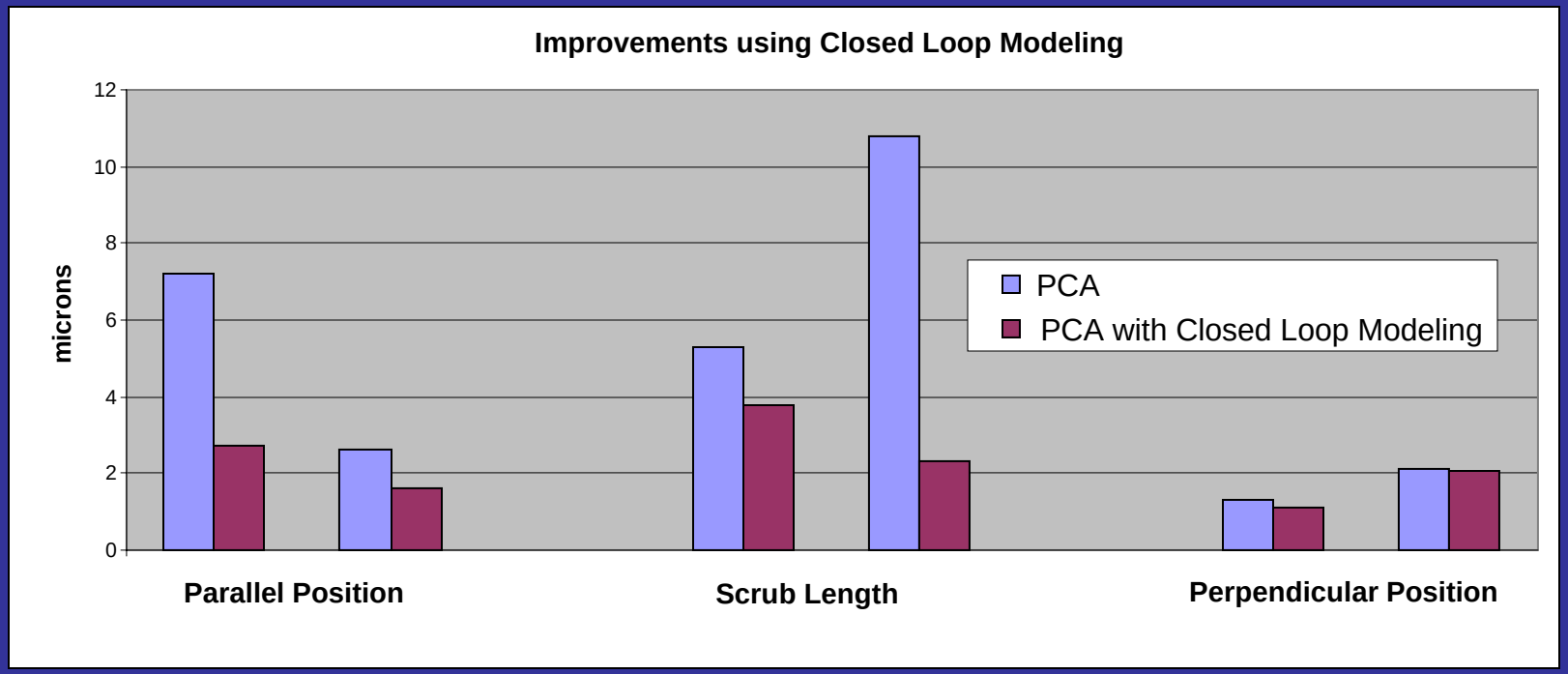
Closed Loop Model Results: Study #2

Closing the Loop



- **Closed Loop Modeling improvements**
  - 1.6X improvement in Parallel Scrub Position
  - 4.7X improvement in Scrub Length

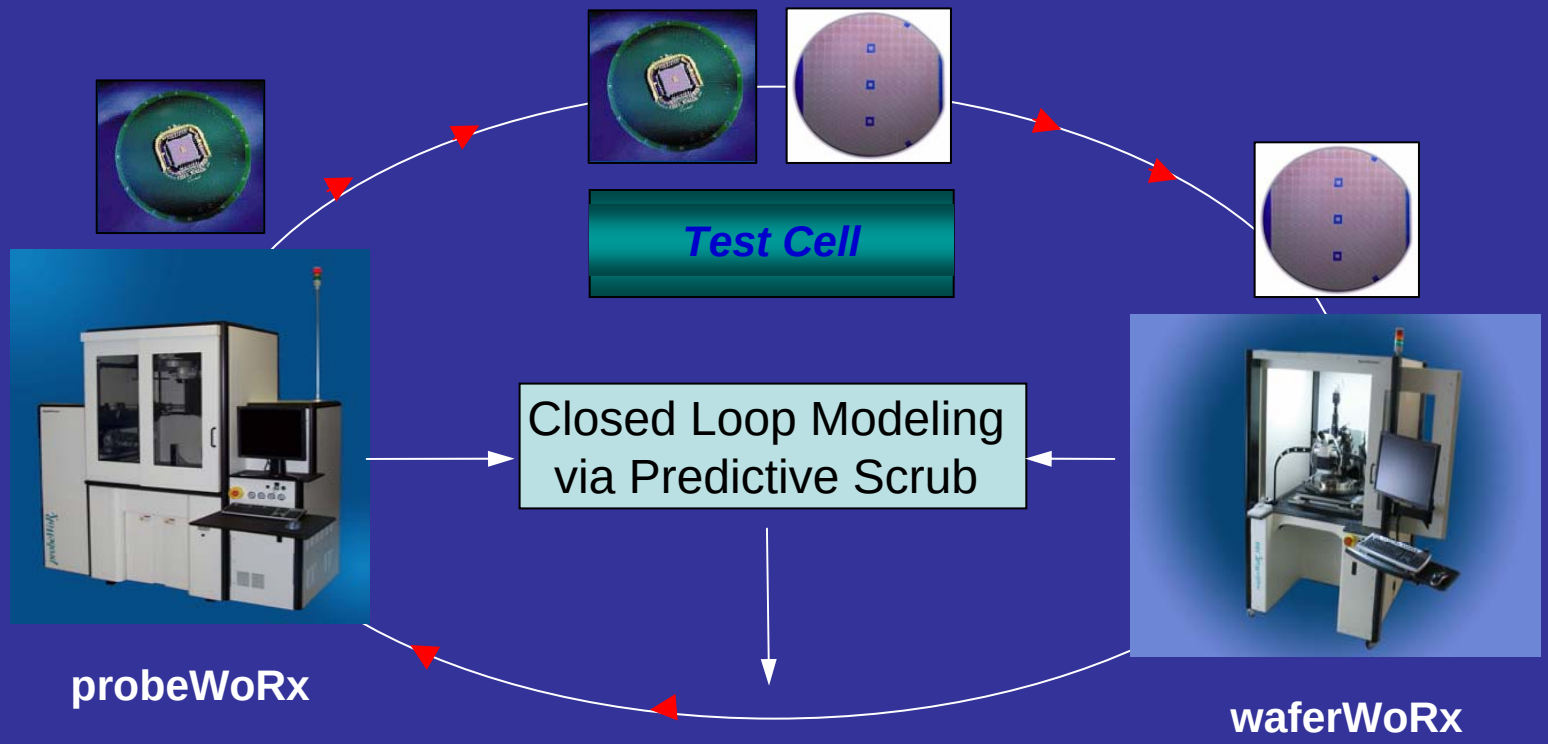
Test Cell Improvements Summary: All Studies



1. Good results between PCA and test cell when data measurement are insensitive to differences
2. Closed Loop Modeling enables significant improvements for Scrub Length and Scrub Position
3. Closed Loop Model enabled PCA can deliver optimized probe cards to the test cell via predicted probe card measurements

What is the best method to optimize the performance of the probe card in the test cell?

- Build Closed Loop Model
- Use a Closed Loop Model enabled PCA to deliver optimized probe cards to the test cell via predicted probe card measurements



Acknowledgements

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