Prober and Probe Card Analyzer Performance Under Load

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Presentation Agenda

- Motivation
- Loads and Deflection Mechanisms
- Probe Tip Mechanics
- Loaded Prober and Probe Card Analyzer (PCA) Performance
- Summary and Conclusions

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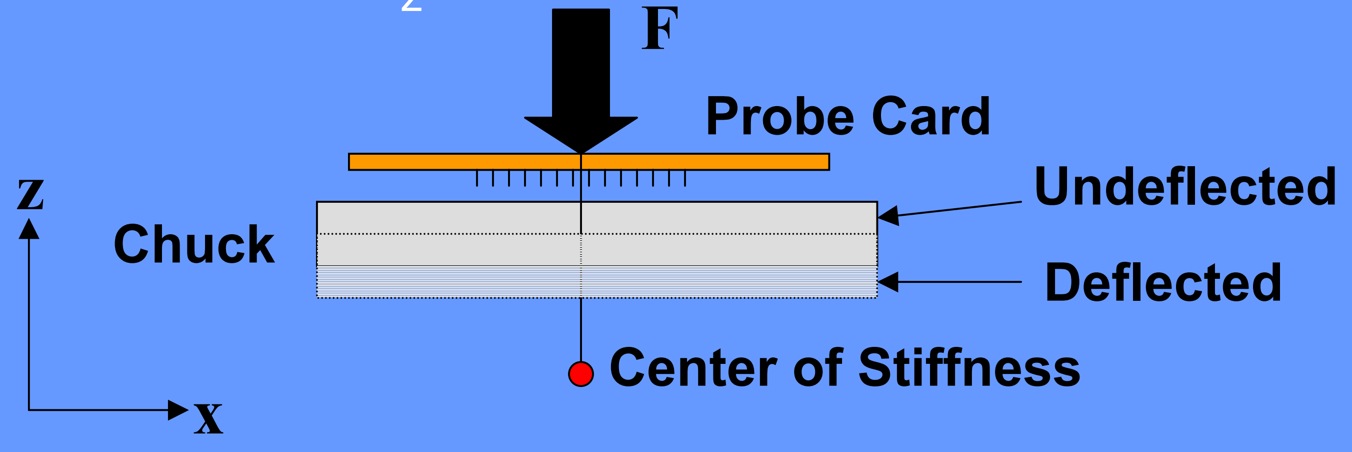
Motivation

- Increasing Loads + Tighter Accuracy
  - No matter how stiff we design stages, if we're driven to scrutinize closely enough, we'll always see the effects of deflection under load
    - Deflection can impact yield
    - ⇒ Deflection under load increasingly important
- Presentation Objective:
  - Understand manifestations of deflection under load to aid problem identification
  - Suggest means of reducing effects of deflection under load

Normal Loads and Deflections

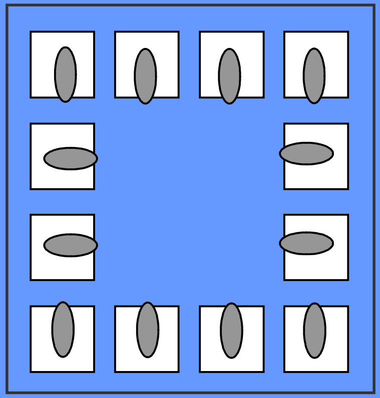
- Direction: Perpendicular to wafer and probe array surface
- Origin: Probe tip stiffness
- Generally linear with overtravel
- Vertical probe technology can be non-linear
- z-direction compliance ⇒ z-direction deflection
- Deflection: $\Delta z = F\, c_z$



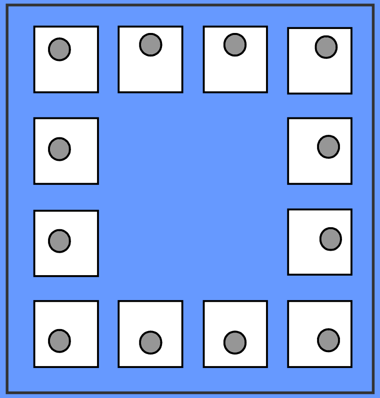
Normal Loads and Deflections

- Normal load effects on scrub
  - z-deflection reduces overtravel ⇒ shorter scrubs
  - Normal force reduced
  - Overtravel can be adjusted to account for expected compliance
  - Adjustment errors produce longer or shorter scrubs

Overcompensated Overtravel



Undercompensated Overtravel



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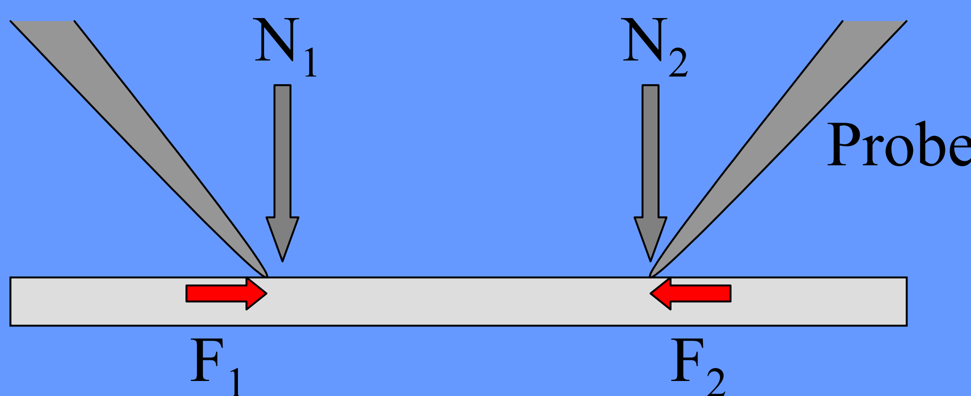
Transverse Loads and Deflections

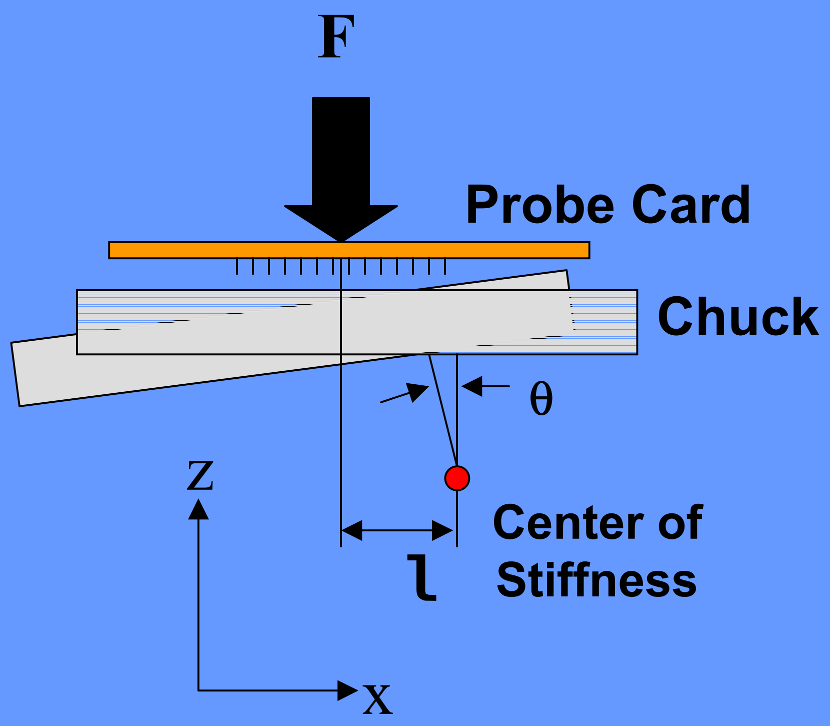
- Transverse Loads
  - Direction: In-plane
  - Origin: Probe tip friction
  - Symmetry: Transverse loads largely cancel on average
  - Potential for deflection-induced errors with asymmetric probe orientations



$N_1 \cong N_2$ $F_1 \cong F_2$

Torsional Loads and Deflections

- Origin: Center of load does not pass through center of stiffness
- $\Rightarrow$ Rotation about center of stiffness
  - Torque: T = F l
  - Rotation: $\theta = F\, l\, c_{rot}$
- Effects:
  - Dependent on center of stiffness
  - Lateral deflection - often dominant
  - Vertical deflection

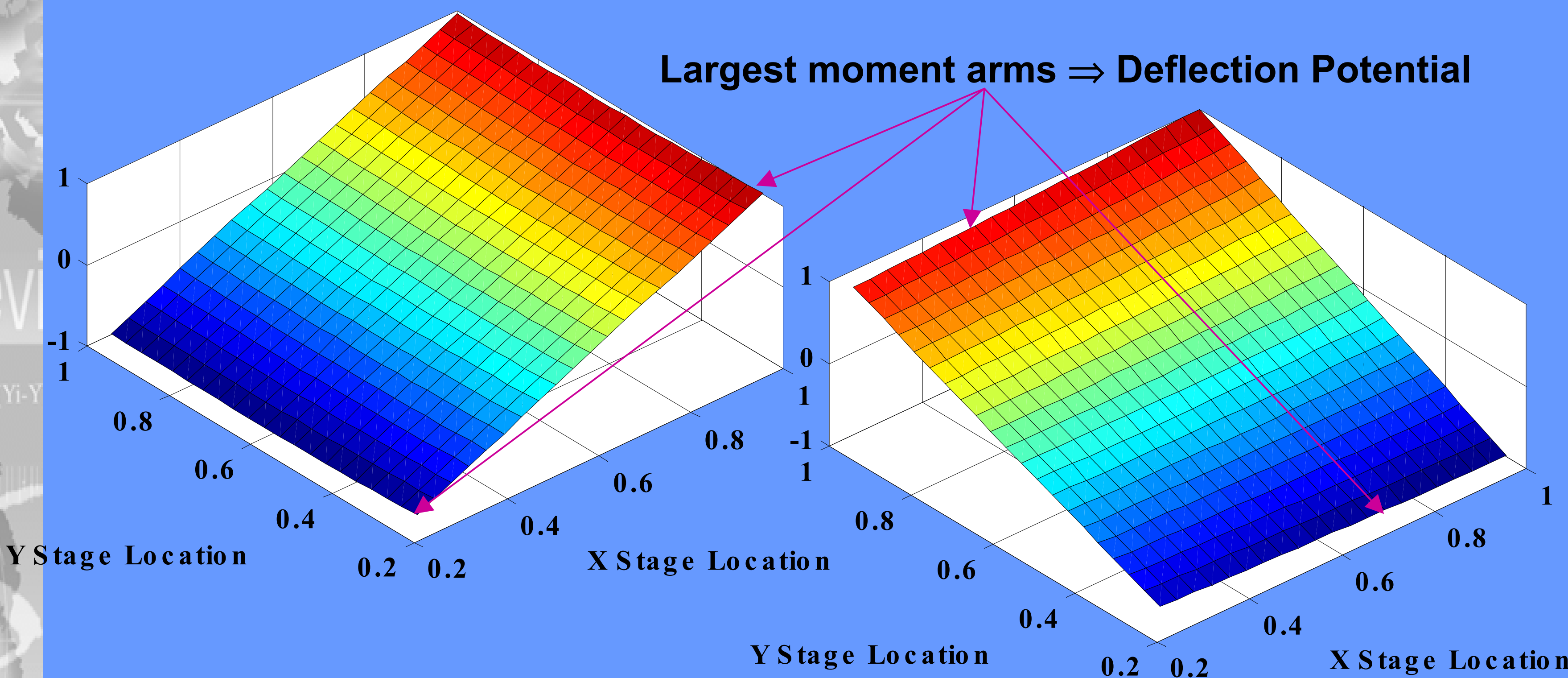


Center of Stiffness Offset

Normalized Offset Relative to Center of Force

Goal: Minimize Offset

X Center of Stiffness Offset ***Y Center of Stiffness Offset***



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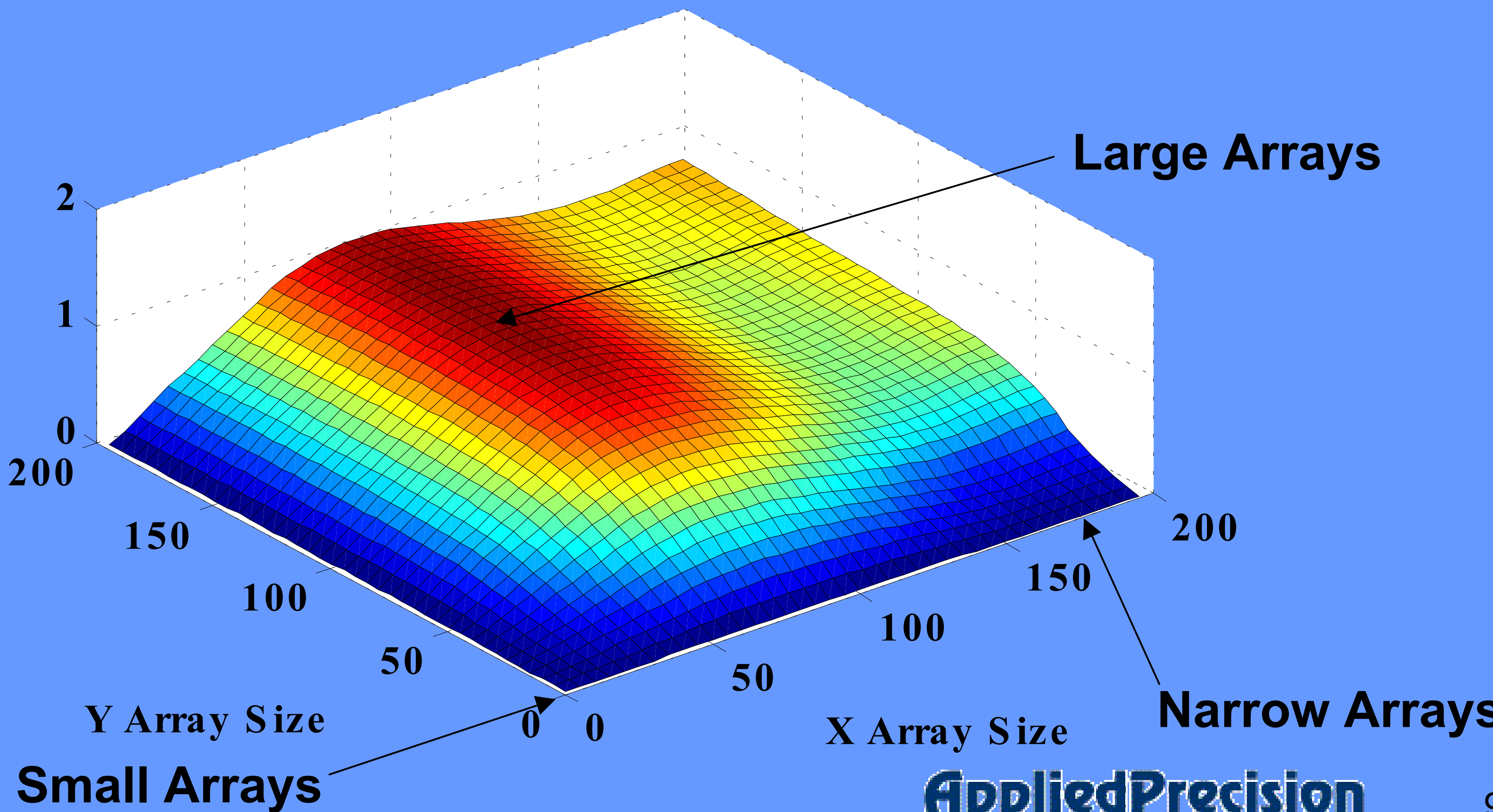
Chuck Deflection from Torsion

3σ Normalized Scrub Alignment Variation Under Load vs Array Size

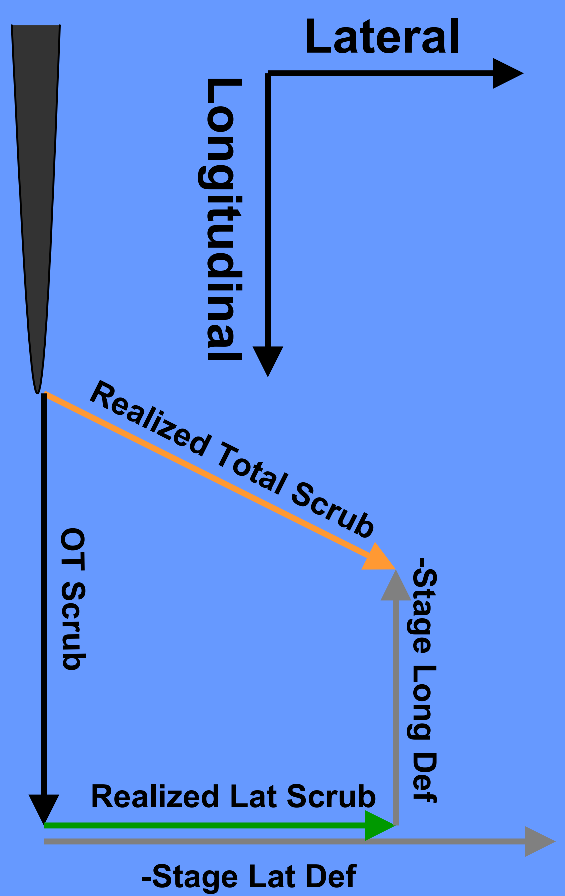
- **Factors**
  - Array size
  - Number of pins on chuck
  - Center of load relative to stiffness



Probe Geometries

- Cantilever Probes
  - Longitudinal deflection
    - Stiff axis
    - 1:1 deflection into scrub
  - Lateral deflection
    - More flexible axis
    - Probes tend to drag somewhat - reduces sensitivity to deflection effects
    - <1:1 deflection into scrub
      - 0.3:1 common

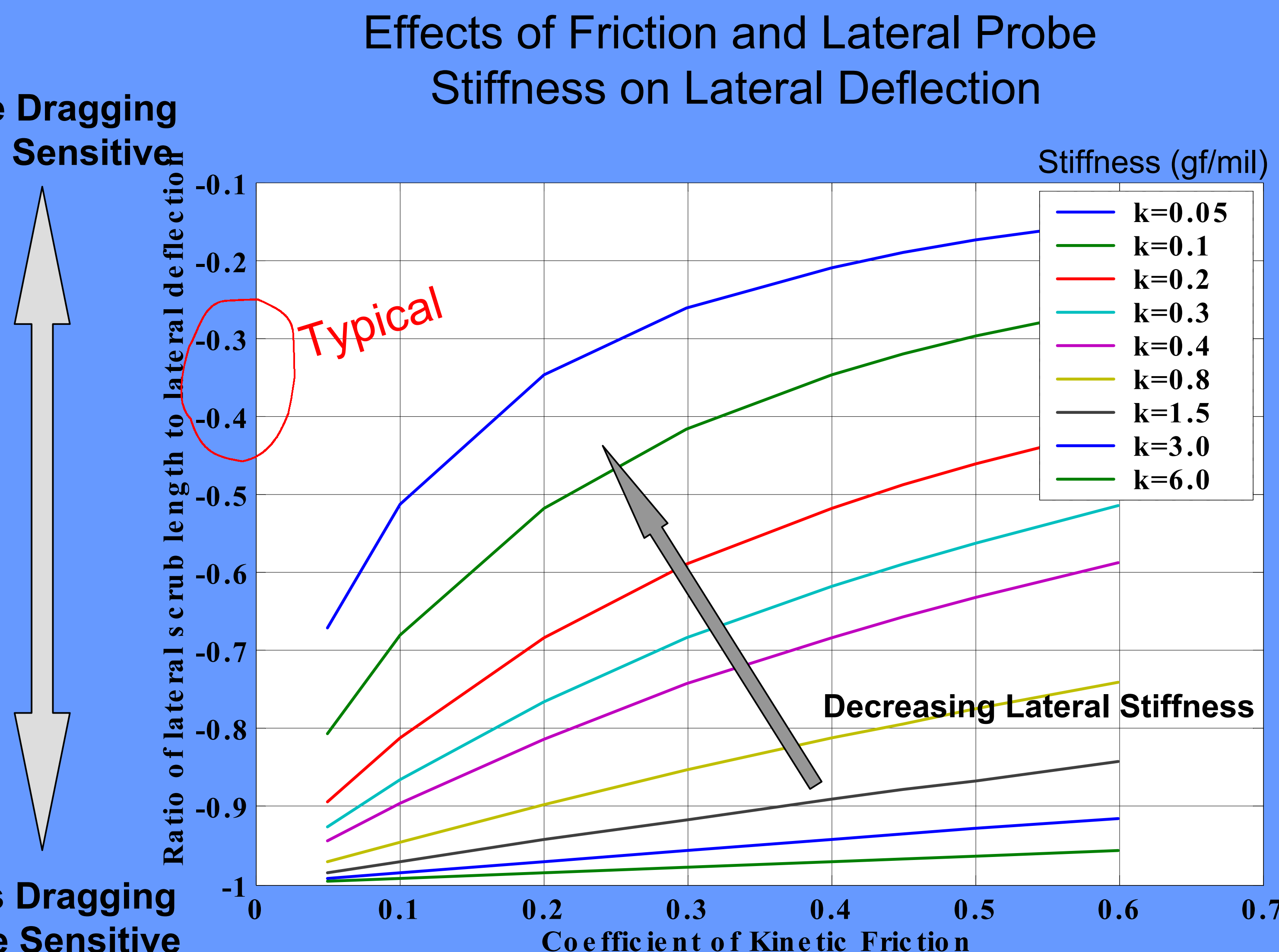
Top View



Cantilever Probe Lateral Deflection

More Dragging
Less Sensitive

Less Dragging
More Sensitive



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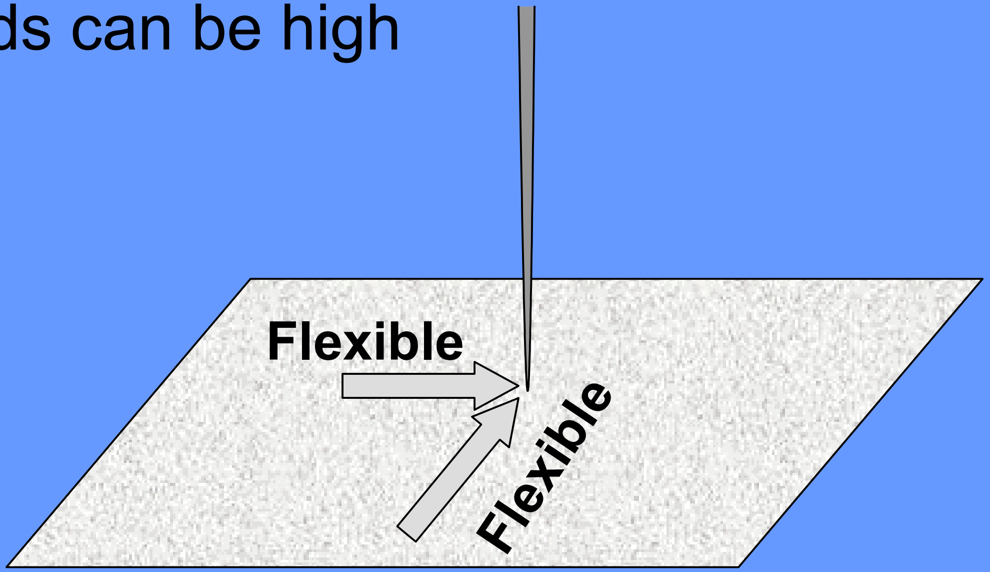
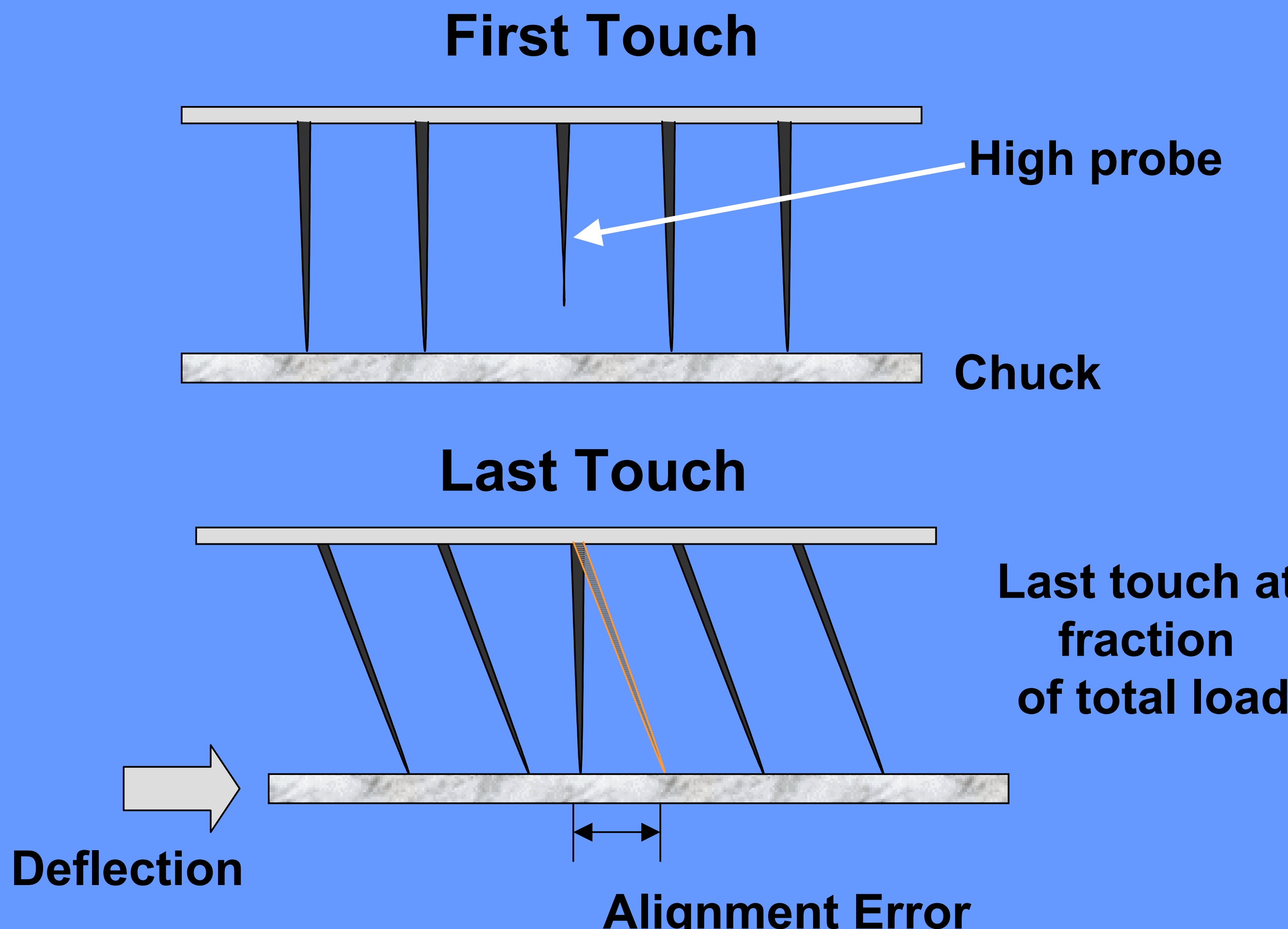
Probe Geometries

- Vertical Probes
  - Relatively compliant with respect to in-plane forces (e.g. friction)
  - Probes are “dragged” with chuck as it deflects
  - Deflection induced error governed by high probes
  - Highly planar arrays forgiving of deflection even though loads can be high



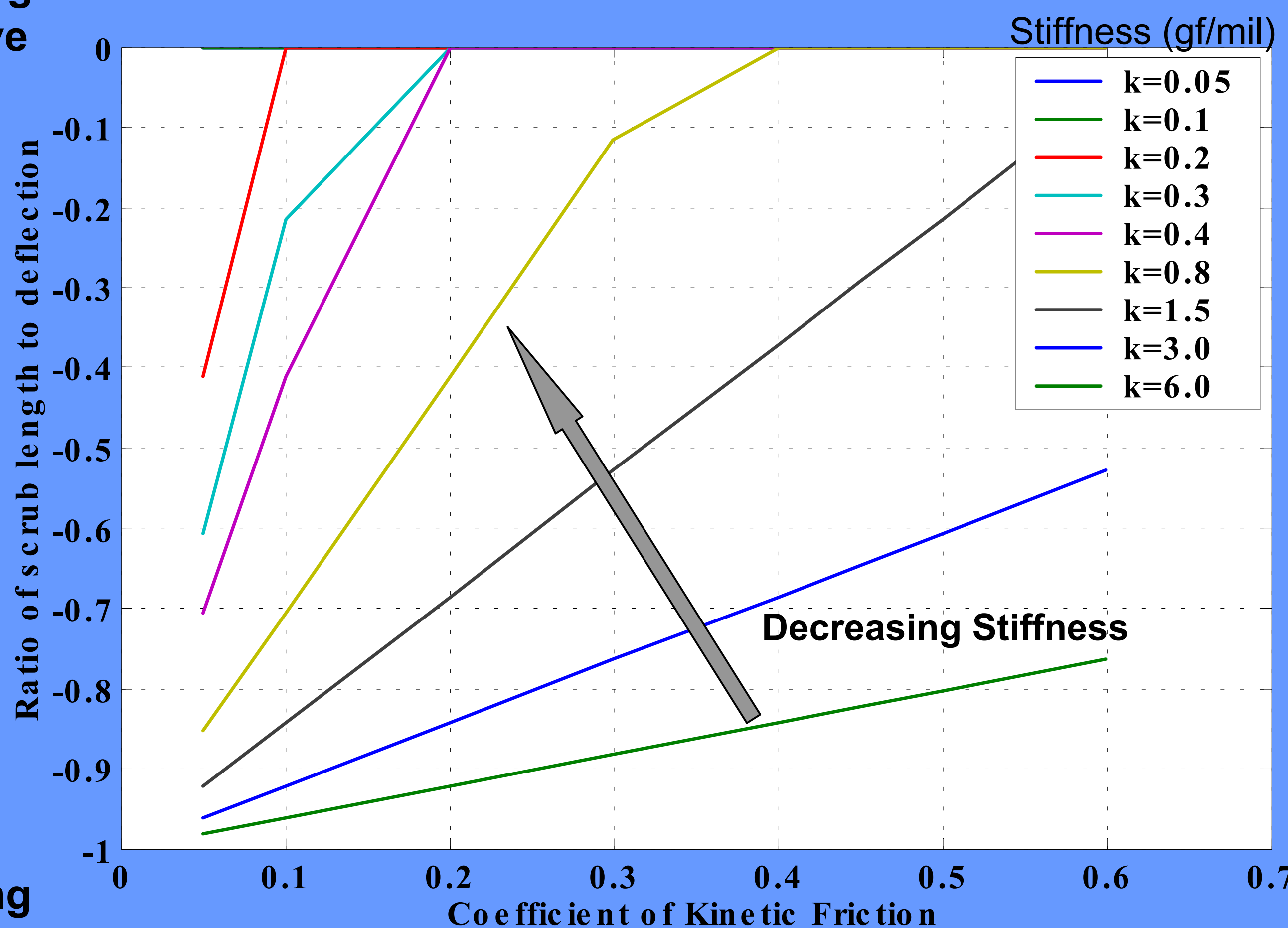
Vertical Probes: Deflection Effects



Vertical Probe Deflection

Effects of Friction and Probe Stiffness on Deflection

More Dragging
Less Sensitive



Less Dragging
More Sensitive

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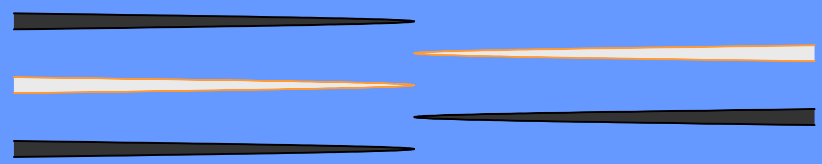
PCA: Cantilever Deflection Estimation

- Co-located, opposing probes

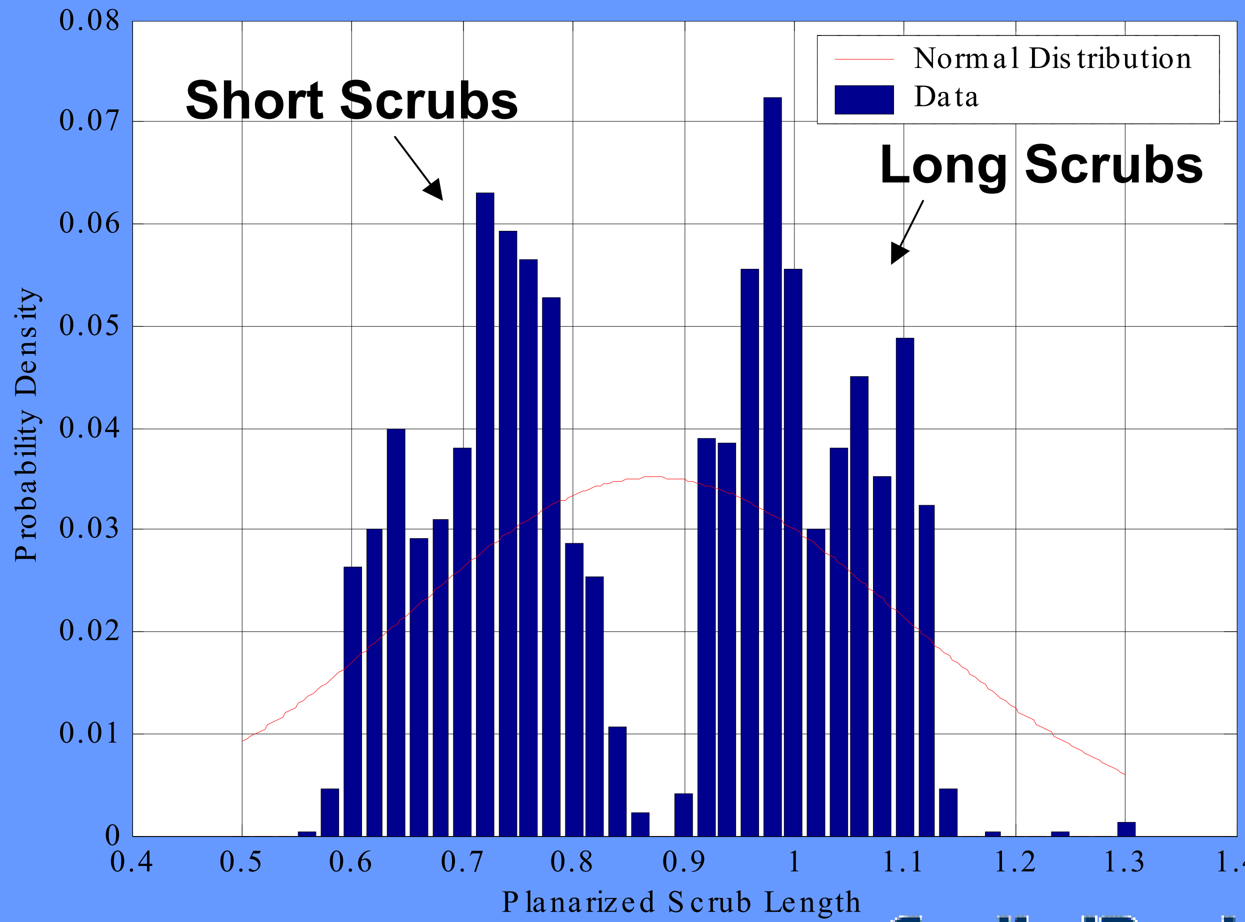


  - Co-located ⇒Equiv loads, Equiv deflections for PCA
  - Equal and opposite variations in scrub length
  - Equal and opposite variations in scrub angle
  - Data can be used to estimate deflection
- Deflection ⇒ bimodal distribution of scrub length and/or scrub angle
  - Dependent on compliance in each axis

Cantilever: Statistical Distribution

High Stage Compliance in Scrub Direction

Normalized Scrub Length Distribution



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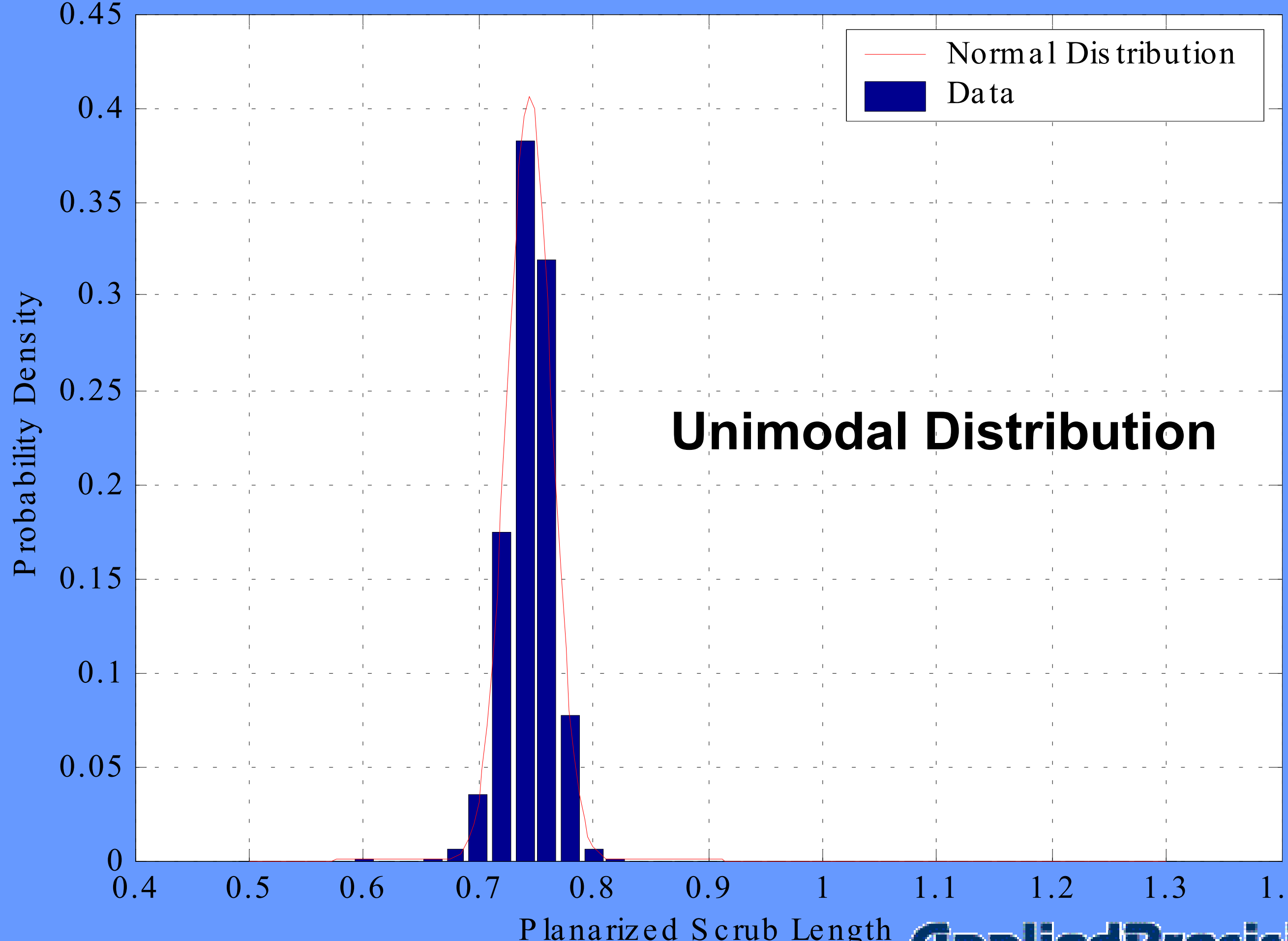
Cantilever: Statistical Distribution

Low Stage Compliance in Scrub Direction

Normalized Scrub Length Distribution



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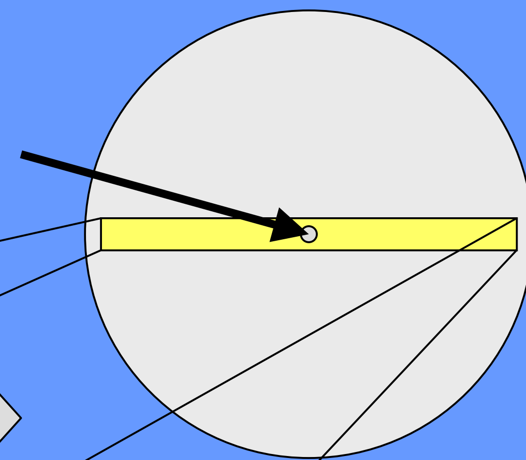
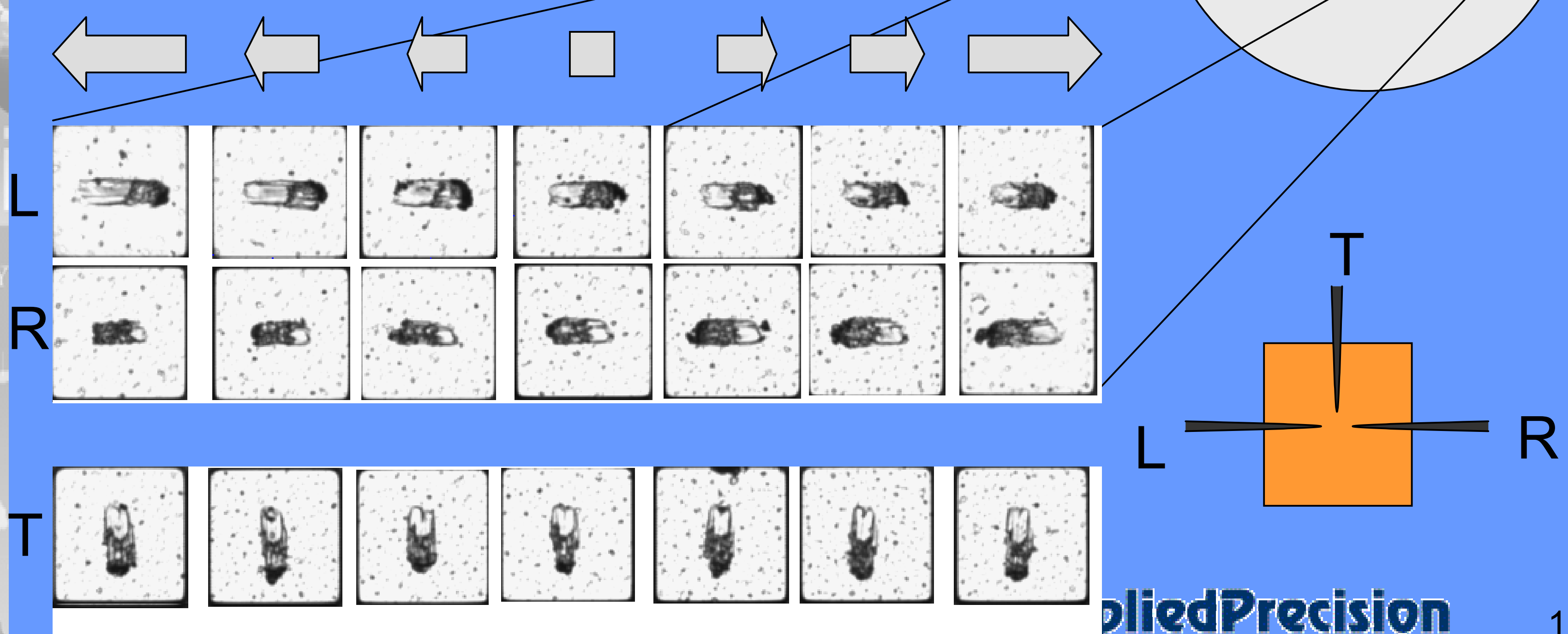
Prober: Cantilever Scrubs

- Rotation under torsional load ⇒ lateral deflection
- Wafer scrub example
  - Center of stiffness at wafer center
  - 1 x 2 DUT





Deflection Compensation

- Modeling & Estimation
  - Model chuck compliance as a function of location
    - Experimentally determine load/displacement influence coefficient map
    - Estimate influence coefficients based on known component values and FEA
  - Model probe loads
    - Nominal probe gram force parameter and overtravel
    - Calculate total load and load centroid
  - $\Rightarrow$ Estimate Chuck Deflection

Deflection Compensation

- Passive Compensation
  - Post-process results, and remove estimated deflection from measurements
  - Possible only for PCA's
- Active Compensation
  - Actively translate chuck using deflection estimates
  - Estimate real-time loads and deflections
  - Any prober compensation needs to be active

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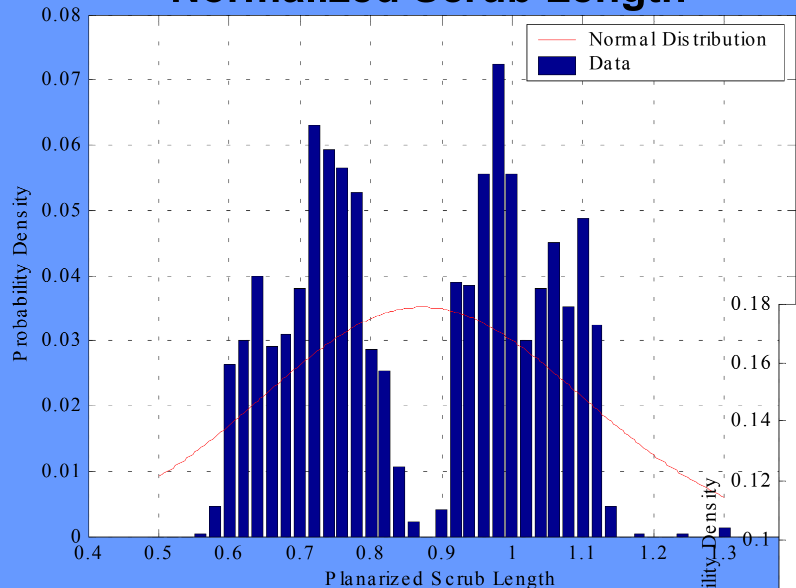
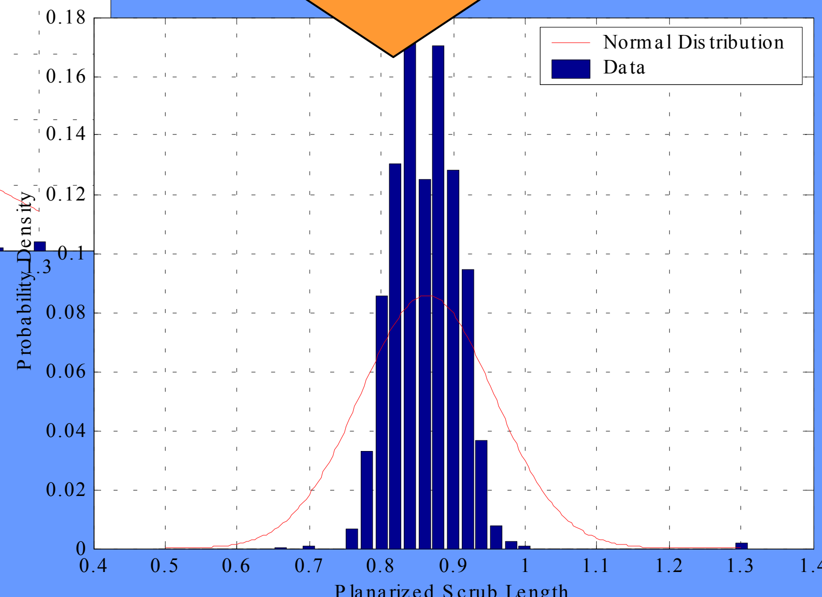
Deflection Compensation

- Deflection Compensation Example

Normalized Scrub Length



Un-Compensated



Compensated

Conclusions

- Ways to reduce probe scrub errors:
  - Cantilever and Microspring Technology
    - Reduce probe gram force and overtravel
    - Minimize distance from chuck center of stiffness to center of load
    - Optimize card orientation: align probes with least compliant axis if possible
    - Reduce chuck compliance

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Conclusions

- Ways to reduce probe alignment errors
  - Vertical Technology
    - Tighten probe card planarity if possible
    - Minimize distance from chuck center of stiffness to center of load
    - Reduce probe gram force
    - Minimize chuck compliance
    - Overtravel not a significant factor

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Conclusions

- Deflection under load increasingly important issue
- Deflection can be estimated from standard test data, and quantified
- Deflection may be minimized proactively in a number of ways
- Deflection effects may be minimized via compensation