

Actual vs. Programmed Overtravel for Advanced Probe Cards



Tommie Berry - FormFactor Inc.

Keith Breinlinger - FormFactor Inc.



Rey Rincon - Freescale Semiconductor



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Overview

- **Background : What & Why**
- **Measurement Method**
- **Review of Data**
- **Using the Formula**
- **Summary**
- **Future Work**
- **Acknowledgements**

What is AOT/POT? Who Cares?

- Are you using more than 3000 probes with ~3 grams per probe ?
- Or more than 1000 probes @ 10 grams per probe ?
- Then you should CARE !
- Yield, CRES, \$\$\$
- **Full Wafer Probe Cards for DRAM & FLASH**
 - As they moved to high pin counts (>10,000 springs) were forced to accept reality that everything in the system is not infinitely rigid
 - Without it, probes would be greatly under-compressed which can lead to CRES and stability issues
- **Many SOC customers are now using spring counts high enough that they need to consider AOT/POT.**
 - Previous assumption was “What I program on the prober is what the spring is compressed.”
 - When AOT/POT goes below 80-90% this is a poor assumption.

Terminology

AOT = Actual Over Travel of the probe springs

POT = Programmed Over Travel as entered on the prober

k_{total} = spring constant for total system

k_{spring} = spring constant for 1 probe

N = Number of probes

k_{system} = spring constant of prober, headplate, cardholder, chuck and probe card



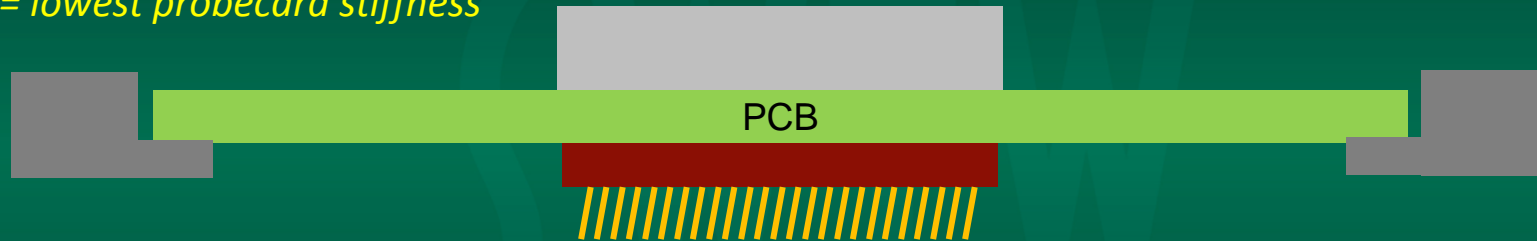
k_1

This is a mechanical spring (not a resistor)

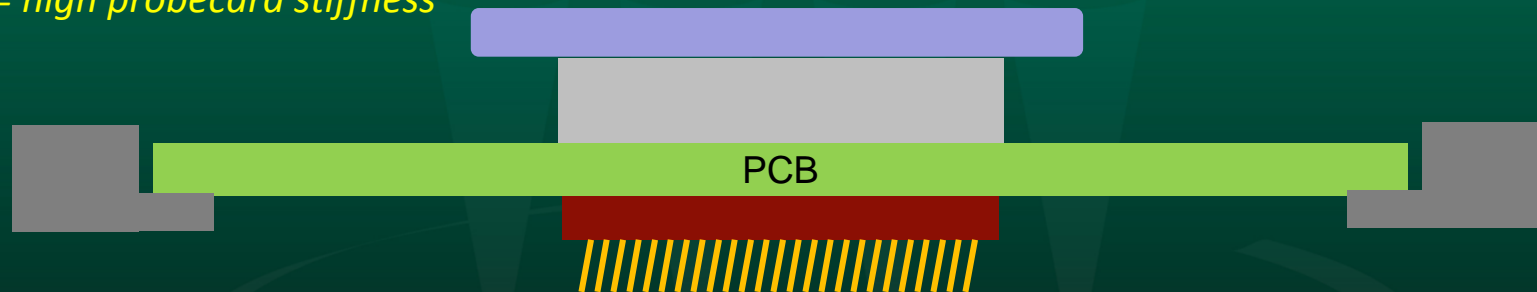
Spring constant for that spring

Probe Card Mechanics

Configuration 1: A traditional probe card supported by cardholder
= lowest probecard stiffness



Configuration 2: A probe card supported by cardholder and contacts on tester
= high probecard stiffness



Configuration 3: Probe card supported by cardholder with TSS all the way out to card holder edge
= medium – high probecard stiffness

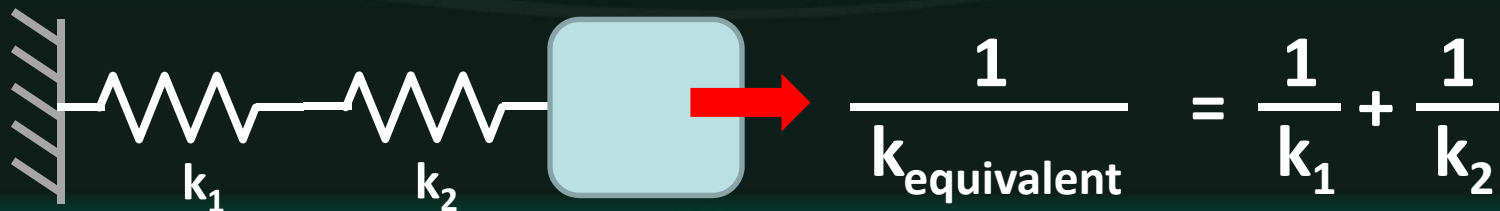


Combining Springs

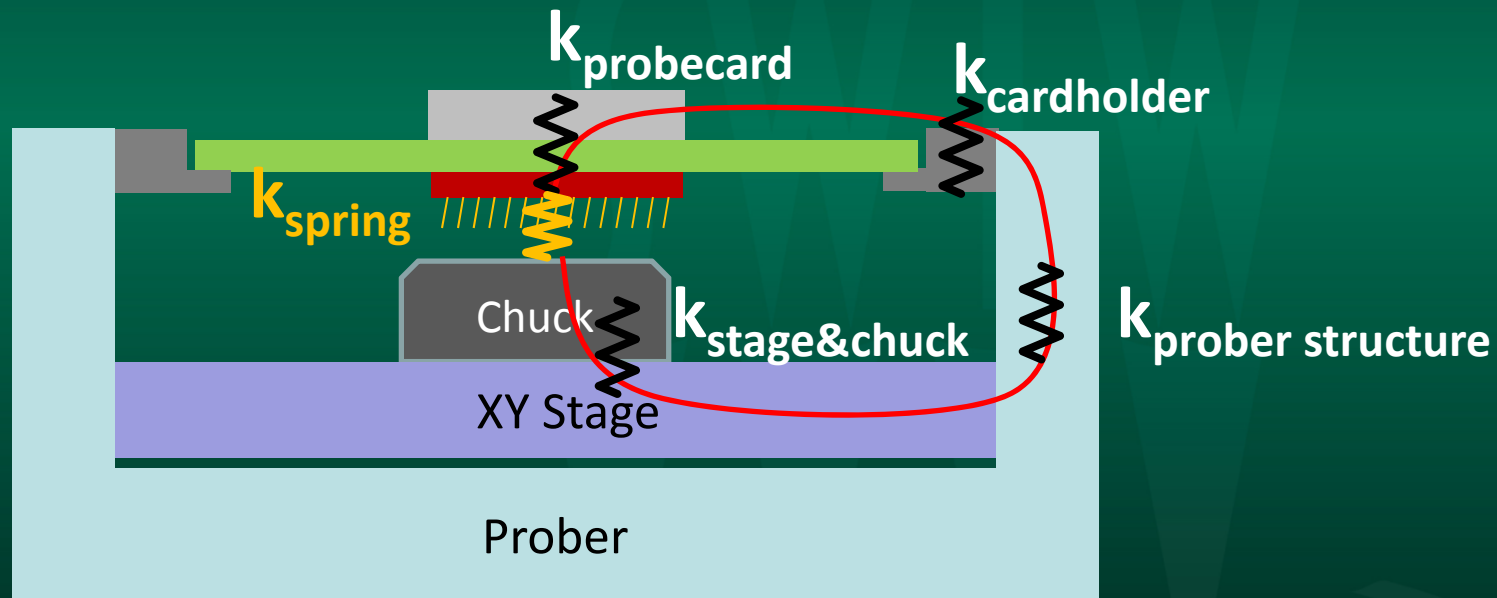
1. Most springs are linear and obeys Hooke's law: $F=k*\delta$. Increase the force and the distance changes linearly with the force. k is the linear spring constant. It has units of Force/Distance, e.g. grams/um or grams/mil
2. Springs in parallel add together. 10 identical springs in parallel act the same as one spring with a k value 10 times larger. (This is the same way to add capacitors in parallel) *Note: the spring is the mechanical analog of a electrical capacitor*



3. Springs in series add as the reciprocal of the spring constants. 10 identical springs in series act the same as one spring with a k value equal to 1/10th the original. (This is the same way to add electrical capacitors in series)



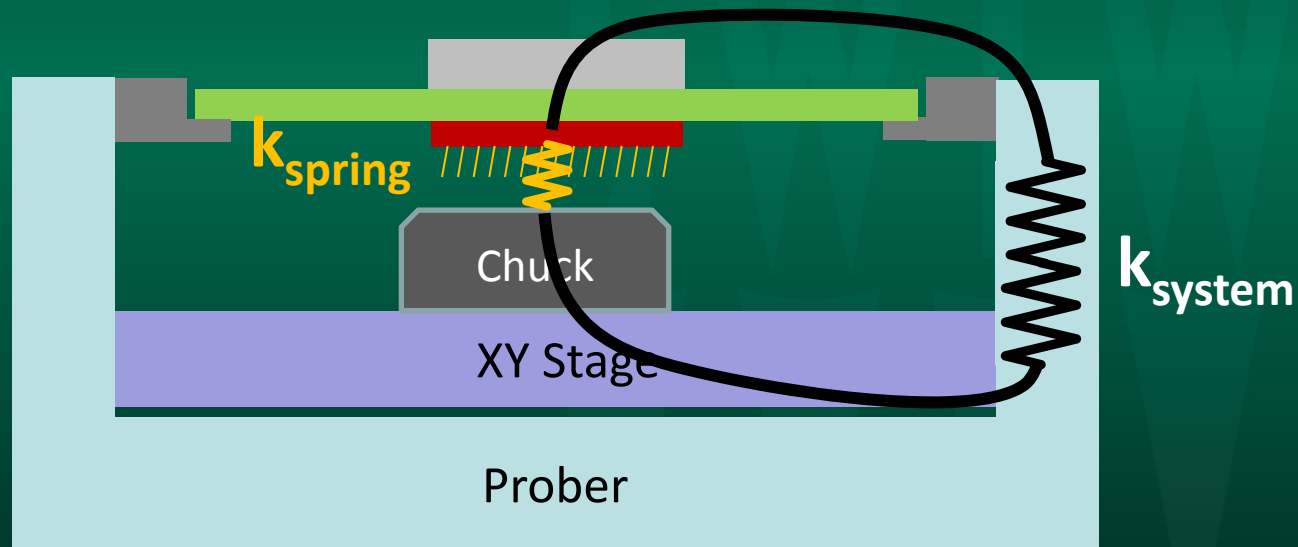
Let's analyze a probe card as a system of springs in parallel and in series



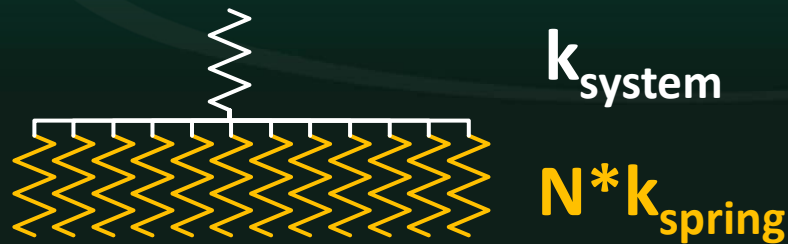
We have a group of springs in series that make up the system:

$$\frac{1}{k_{system}} = \frac{1}{k_{probecard}} + \frac{1}{k_{cardholder}} + \frac{1}{k_{prober\ structure}} + \frac{1}{k_{stage\ \&\ chuck}}$$

Let's analyze a probe card as a system of springs in parallel and in series



All the springs on the probe head are in parallel with one another:



All the springs on the probe head are in series with the system:



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Let's analyze a probe card as a system of springs in parallel and in series

We have multiple springs in series that make up the system:

$$\frac{1}{k_{\text{system}}} = \frac{1}{k_{\text{probecard}}} + \frac{1}{k_{\text{cardholder}}} + \frac{1}{k_{\text{prober structure}}} + \frac{1}{k_{\text{stage\&chuck}}}$$

We have multiple springs in parallel (all the probes together):

$$k_1 + k_2 + k_3 \dots = N * k_{\text{spring}}$$

Putting it all together (system and probe springs are in series):

$$\frac{1}{k_{\text{total}}} = \frac{1}{k_{\text{system}}} + \frac{1}{N * k_{\text{spring}}}$$

Deriving the AOT/POT formula

$$F_{\text{springs}} = (N * k_{\text{spring}}) * \delta_{\text{spring}}$$

$$F_{\text{total}} = k_{\text{total}} * \delta_{\text{total}}$$

$$\frac{\text{AOT}}{\text{POT}} = \frac{\delta_{\text{spring}}}{\delta_{\text{total}}} = \frac{F_{\text{spring}} / (N * k_{\text{spring}})}{F_{\text{total}} / k_{\text{total}}}$$

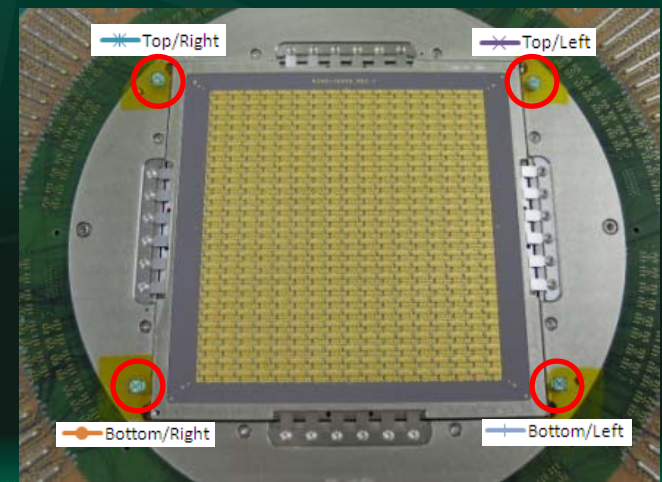
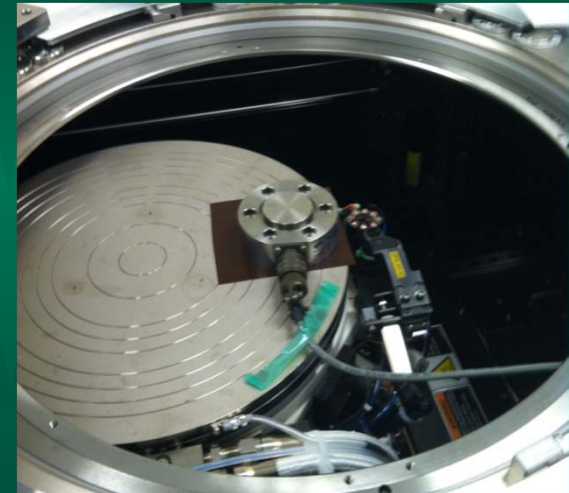
$$\frac{\text{AOT}}{\text{POT}} = \frac{k_{\text{total}}}{N * k_{\text{spring}}}$$

Force on springs is the same as force on total – so these cancel.

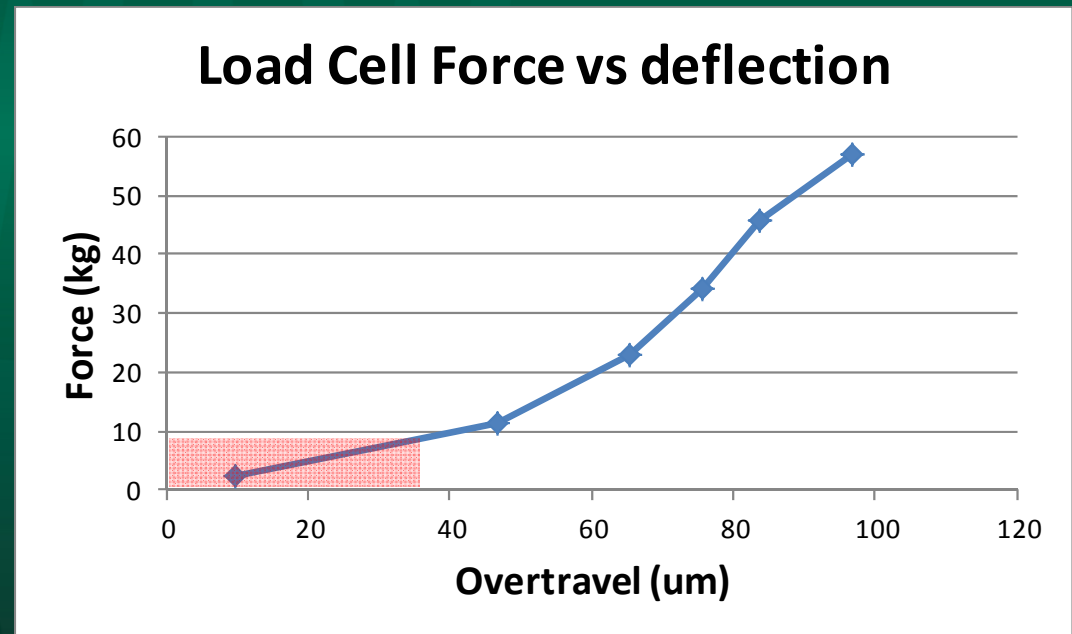
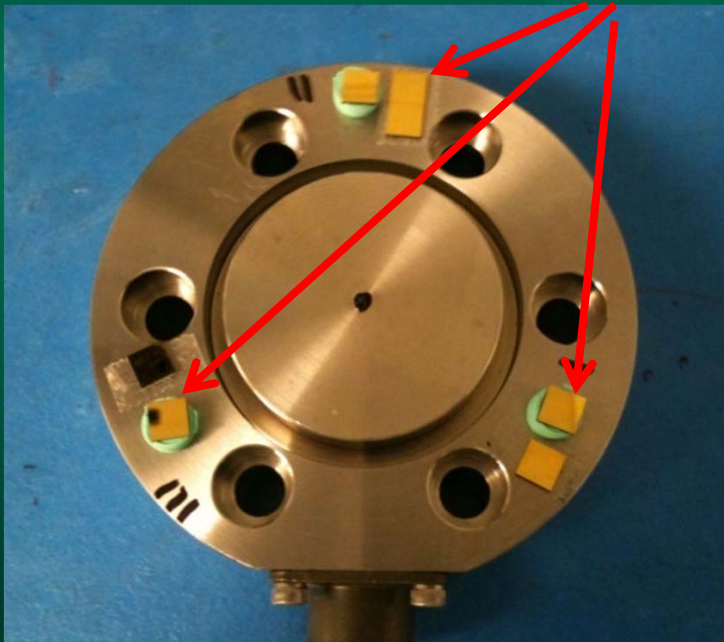
Measurement Methods

- **3 measurements methods:**

- To find k_{system} : use a load cell on the chuck and a probecard with no probe springs.
- To find k_{spring} : use a FFI kmapper – a small force/displacement machine – could also use CETR tribometer or other micro force/displacement measurement machines
- To find k_{total} : use clay puck technique on a full probecard in the prober



Measuring our load cell deflection



- Our first test and the data in the electronic version of the presentation (on USB) used an average k value for the load cell from 0-50kg where $k_{\text{loadcell}} = 740 \text{ g}/\mu\text{m}$
- But our two test probe cards were both relatively low pin count and so in that range the $k_{\text{loadcell}} = 244 \text{ g}/\mu\text{m}$

Test #1

- **64 site card**

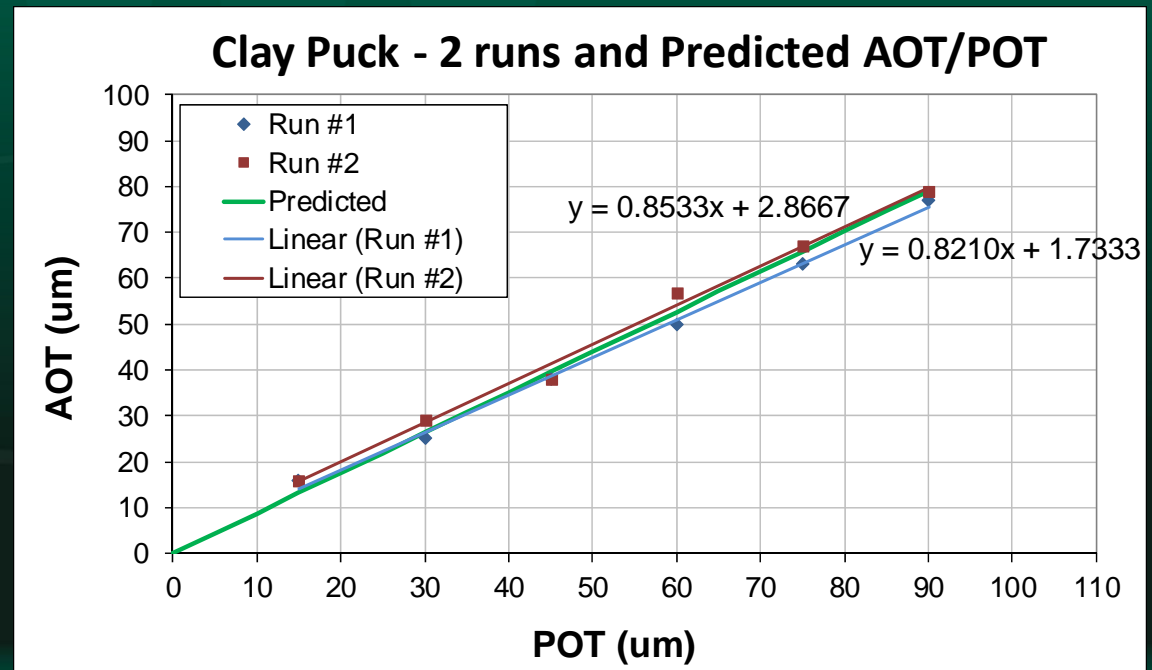
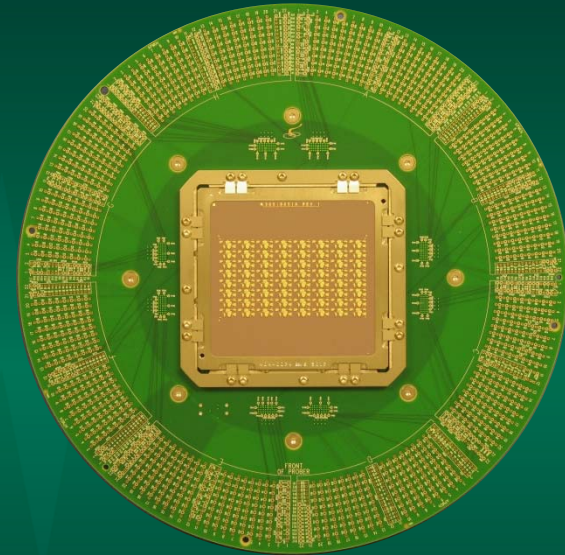
- 3072 springs
- Average $k_{\text{spring}} = 0.96 \text{ g/mil}$
- $N * k_{\text{spring}} = 116.1 \text{ g/um}$

- **Clay puck**

- AOT/POT = 84%
(Average of 2 runs)

- **Calculated**

- AOT/POT = 87%
(from *kmapper* and load cell measurements)



Test #2

- **64 site card**

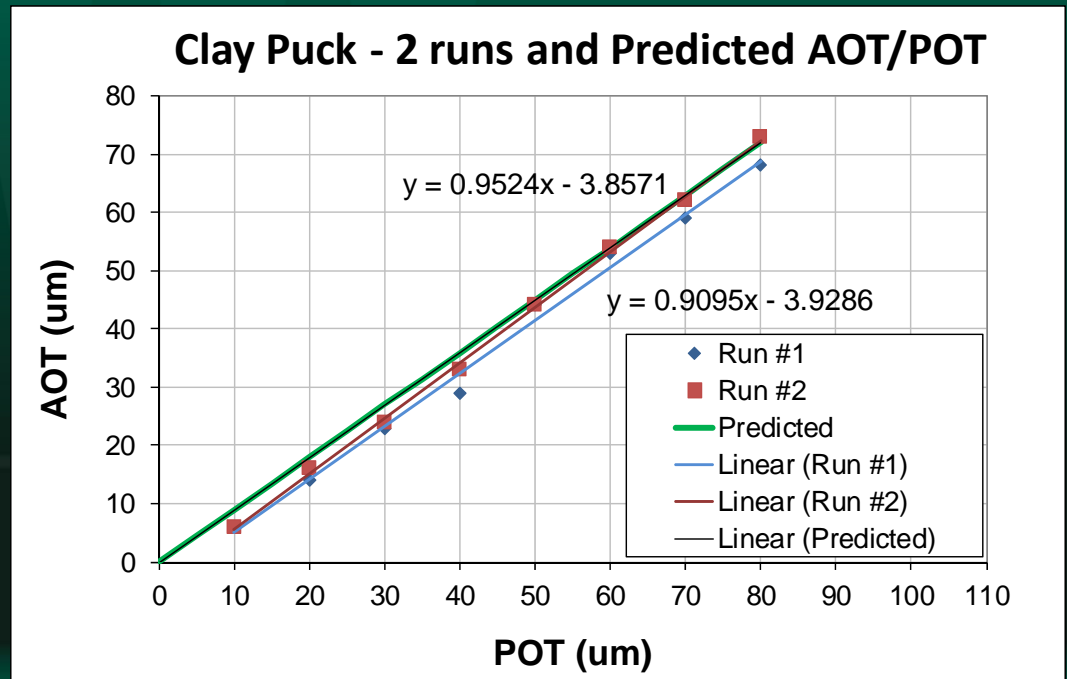
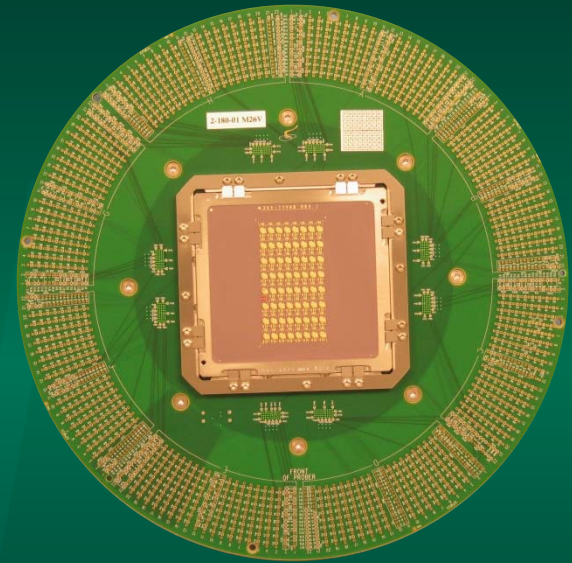
- 2560 springs
- Average $k_{\text{spring}} = 0.91 \text{ g/mil}$
- $N * k_{\text{spring}} = 116.1 \text{ g/um}$

- **Clay puck**

- AOT/POT = 93%
(Average of 2 runs)

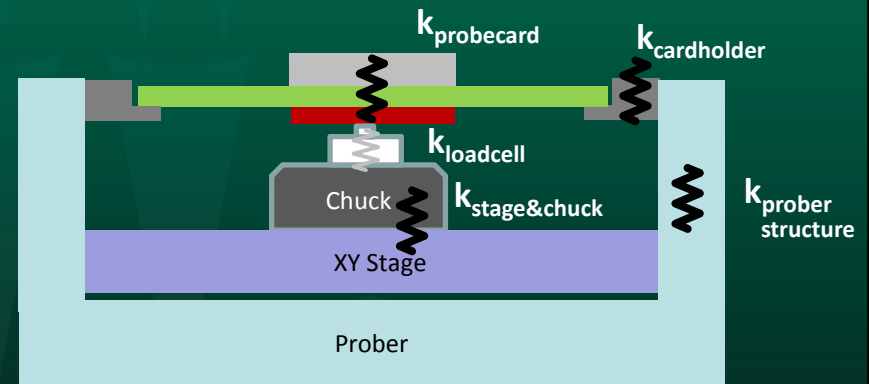
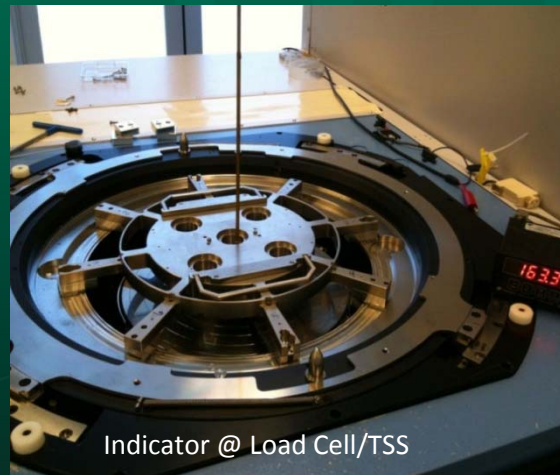
- **Calculated**

- AOT/POT = 90%
(from *kmapper* and load cell measurements)



Understanding k_{system}

$$\frac{1}{k_{\text{system}}} = \frac{1}{k_{\text{probecard}}} + \frac{1}{k_{\text{cardholder}}} + \frac{1}{k_{\text{prober structure}}} + \frac{1}{k_{\text{stage\&chuck}}}$$



Use indicators to measure deflections and understand contribution of each of the major components with load cell inserted in place of springs.

Calculating Actual Chuck Force

$$\text{Force}_{\text{chuck}} = \text{AOT} * \text{N} * k_{\text{spring}}$$

or

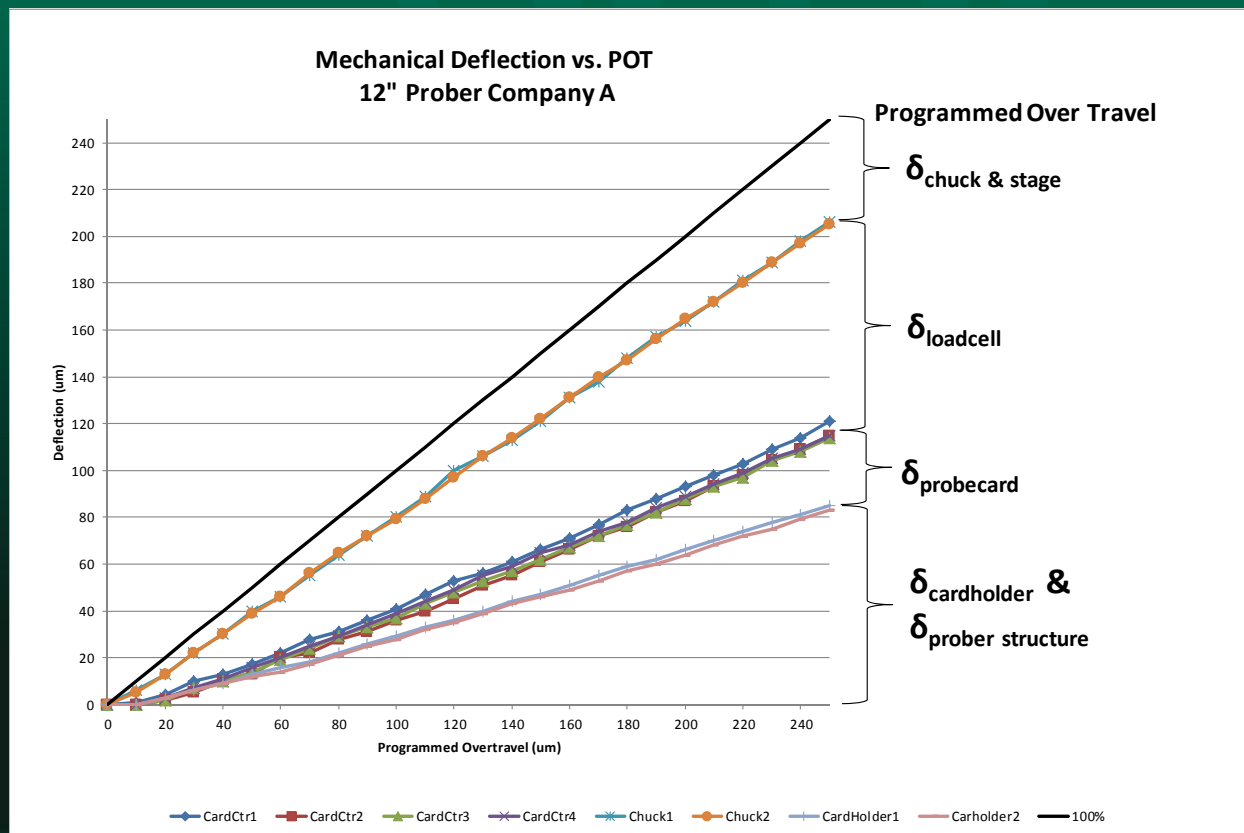
$$\text{Force}_{\text{chuck}} = \text{POT} * k_{\text{total}}$$

This means that regardless of the AOT/POT ratio – the force on the chuck is determined **ONLY** by the k of the springs, the number of springs and the desired overtravel (AOT) of the springs.

Having a weak system (same as a low AOT/POT ratio) – theoretically does not impact spring performance – but practically speaking – it causes greater variation in AOT and variation across the wafer

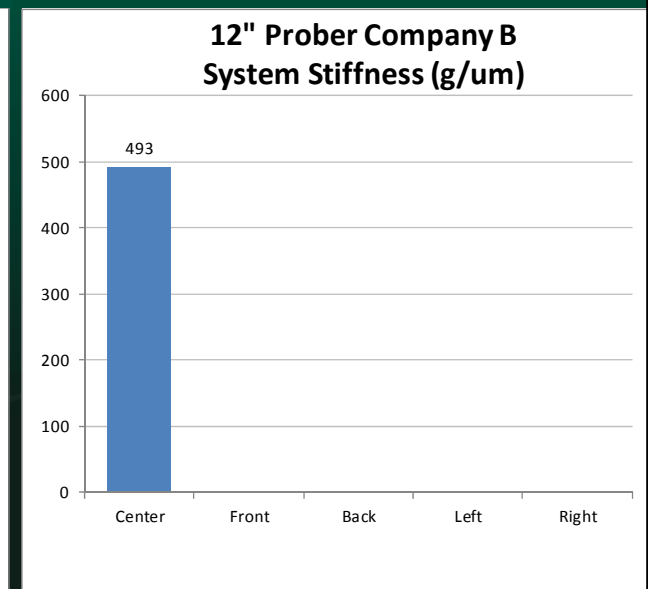
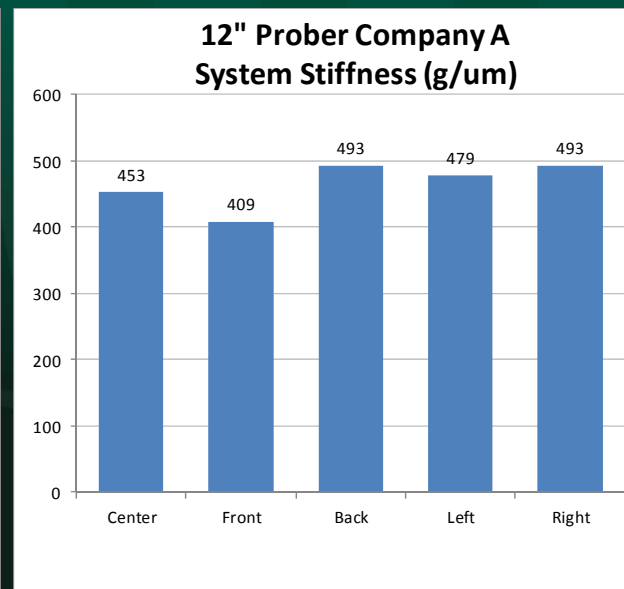
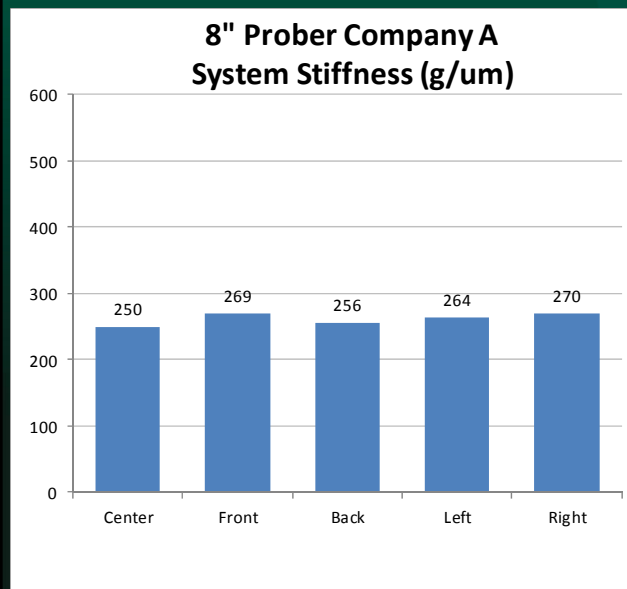
Variations in the system

- Cardholder and load cell are the lowest k (weakest) elements in the measurement. Because load cell is the measurement device – it is not in the real system but must be subtracted out. Quantifying the load cell deflection is the biggest source of error in these measurements.



Variations on the floor

- The prober headplate & cardholder is the most significant portion of the k system. Data collected shows variation depending on the position on the chuck. So AOT/POT ratio varies as the wafer is probed – this may explain some variation in CRES or other measured values across the wafer.



Summary

- **The actual overtravel you get on an array of probe springs is not the same as the value you enter on the prober.**
 - We call this ratio $AOT/POT = \text{Actual Overtravel} / \text{Programmed Overtravel}$.
 - For small pin counts (100 – 1K) this does not matter very much as the ratio is typically >95%
 - For high pin counts (2K to >10K) this matters quite a bit and should be characterized and understood when setting up new probe cards
- **Mechanical springs add in parallel and series the same way you add electrical capacitors.**
 - Regardless of the ratio and how much the system and probe card deflects, the total force required by the prober to compress probes to a desired overtravel is the same. That is – if the AOT/POT ratio is 30% or 95% and you want to compress 5000 springs to 60um AOT, the chuck force will be the same.
 - Using load cells, measured k values and clay puck together will help you characterize your setup.
 - Once your system stiffness is known – future cards that use the same architecture can safely be used with a calculated AOT/POT ratio
- **Other factors beyond AOT/POT ratio can affect probe card performance such as local stiffness of the probe card and position on the prober chuck that may be important for your setup.**

Future Work

- **Make measurements from Center, Left, Right, Front & Back to verify that your prober chuck will have the same AOT for all your touchdowns on the wafer.**
- **POT could be changed with every TD in an extreme situation**
 - 100,000 springs
 - Chuck force = 300Kg
 - Software would have to be written to do this
- **Use this information when specifying your prober.**
- **AOT/POT can not be ignored for high spring counts.**

Acknowledgements

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