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Key Design Practice of High Payload Vertical Probe Card

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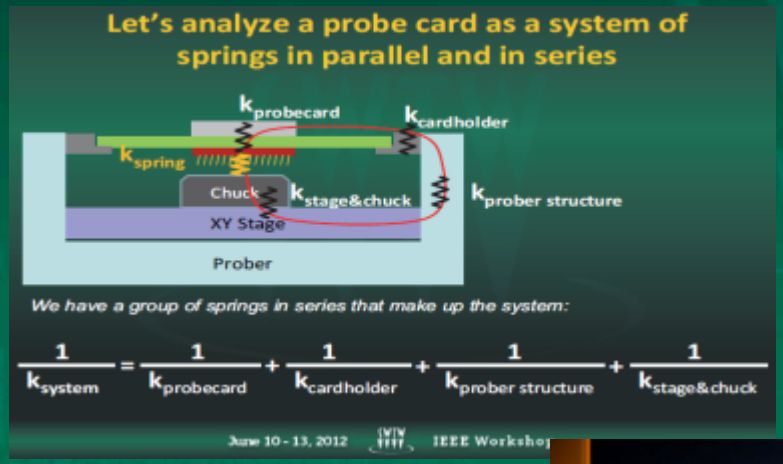
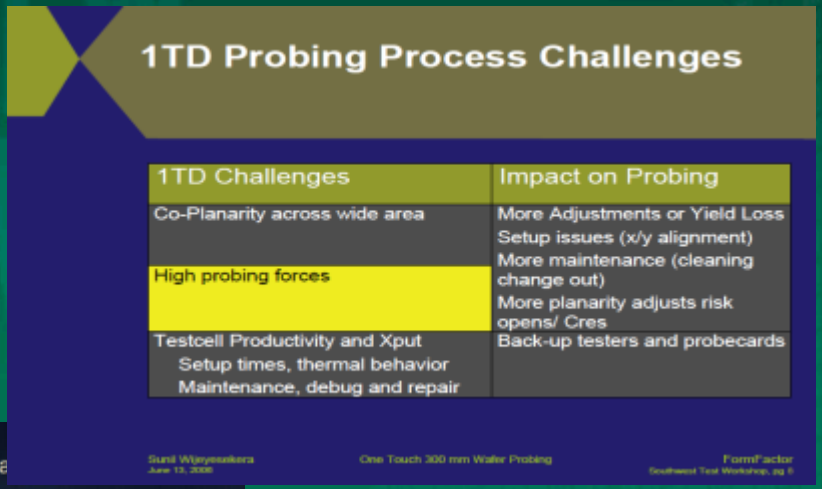
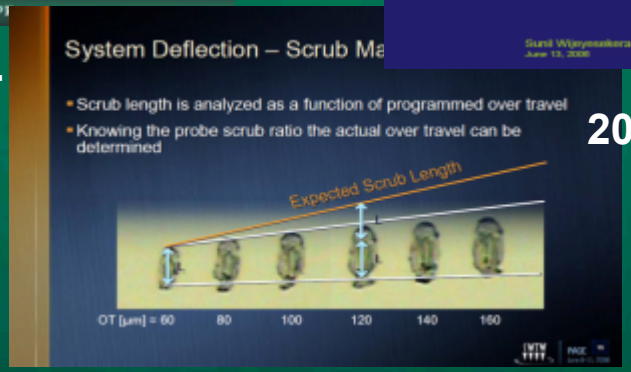
Standing on the Shoulders of Giants



2012 Tommie et al.



2006 Wijeyesekera et al.



2008 Huebner et al.

And More…

- Deformation of the big picture, the system has been addressed in the past. In this presentation we look seriously on one contribution of the system, the probecard, and how to deal with it.

Outline

- Overview
- Measurement Tools & Methods

I. Examining & Improving AOT/POT of a card

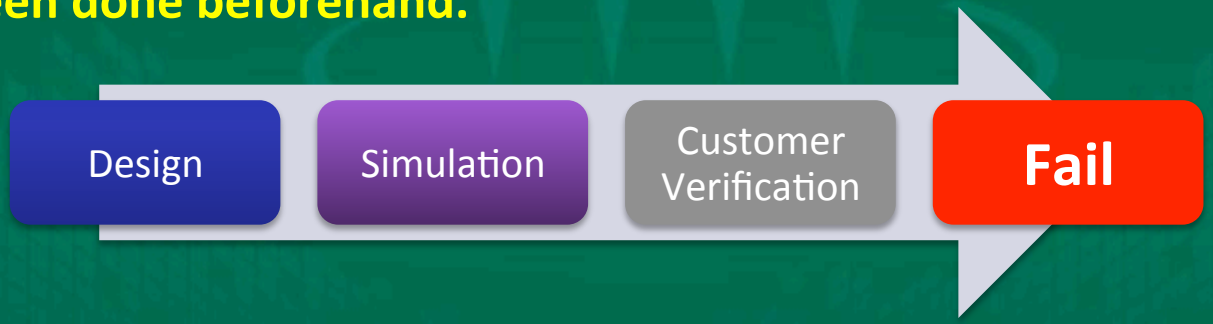
II. Localized Deformation Analysis & Improvement

III. Validation at Customer Site

- Conclusion/Future Studies

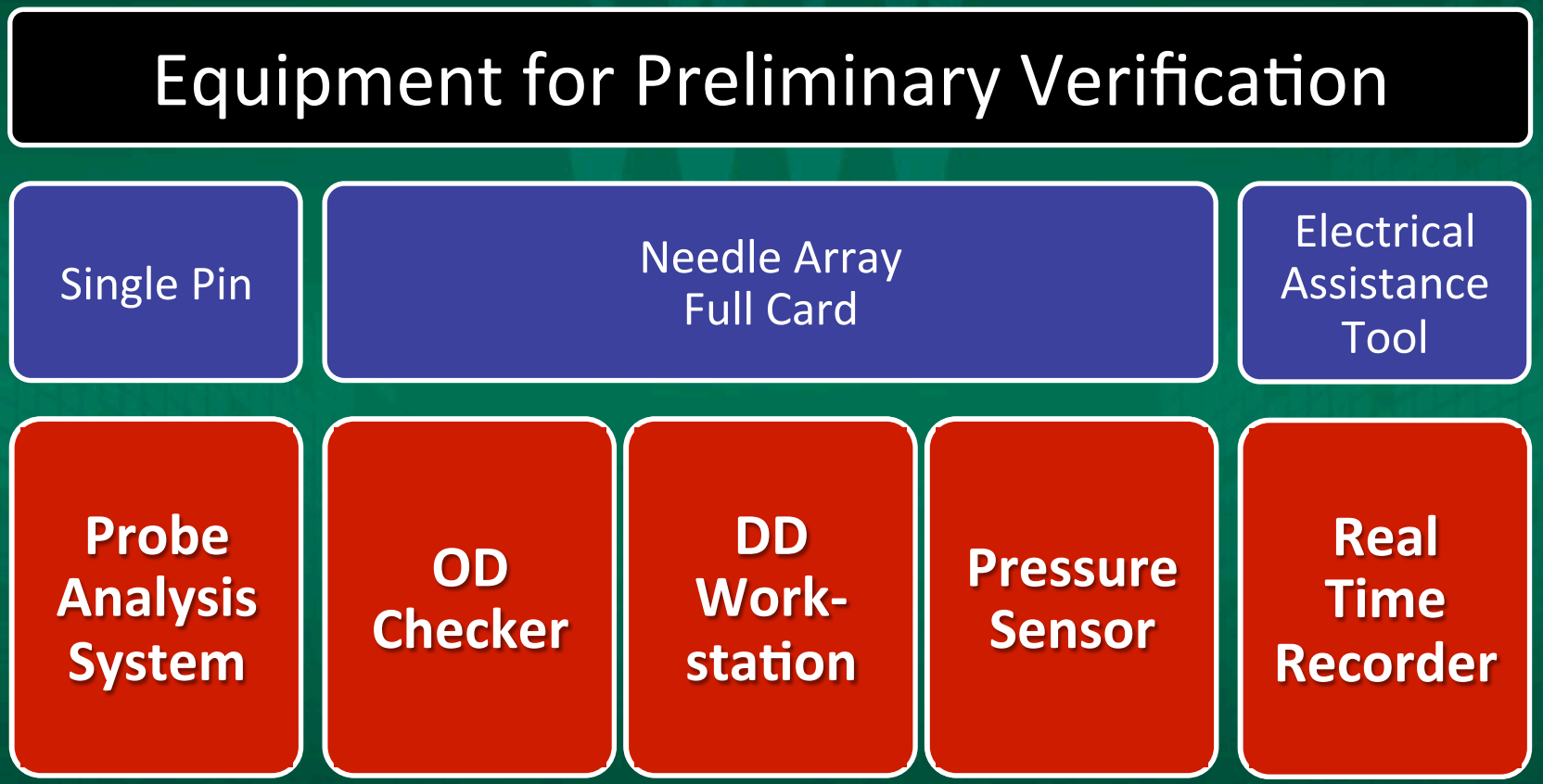
Overview

- POT: The OT which the user input to the testing program
  AOT: Actual OT exerted on the probes
- AOT/POT (A/P ratio) reduces as force rises significantly. This had led to increased time and maintenance cost for our customers even if simulation has been done beforehand.



- As probe card designers, it is critical to verify these high force devices after the design phase before the card reaches our customer.
- Based on ample experience MPI has built multiple tools to measure deflection & A/P using various methods.

Measurement Tools

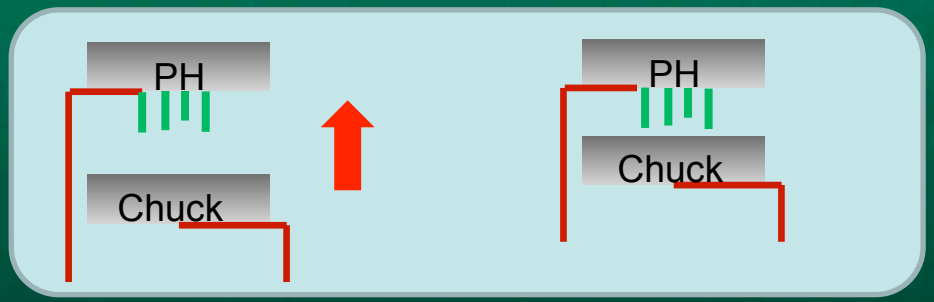


Measurement Methods

- **Global AOT: overall/typical AOT of the array**
  - Card lifted/deflected upward due to deformation
  - Take the distance between PH & chuck as AOT

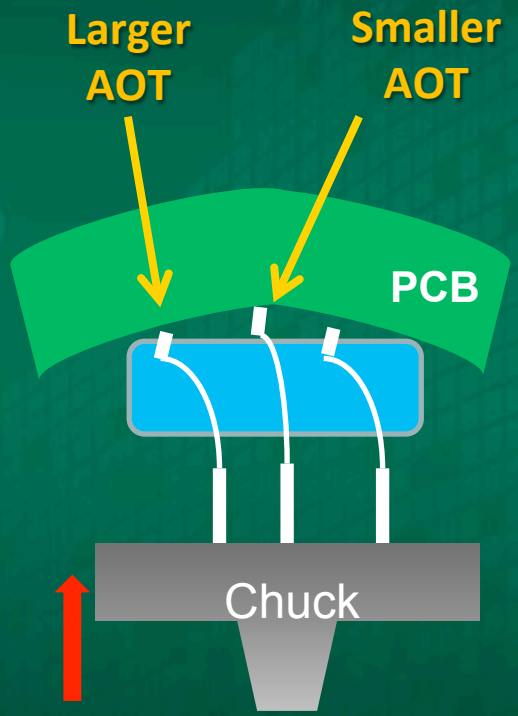
- **Methods**
  - Clay Puck Measurement
  - Dual scale Measurement

AOT =
Chuck reading - PH reading



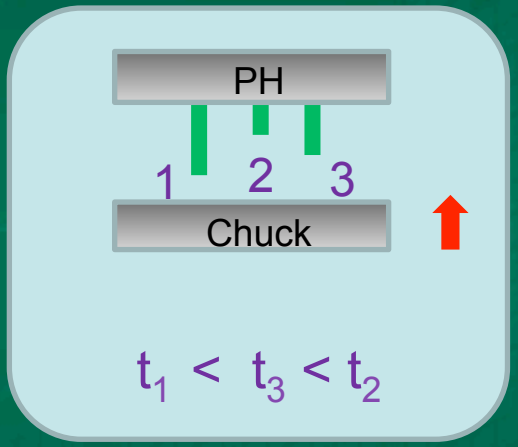
Measurement Methods

- **Local AOT: AOT of individual needles**
  - AOT may vary locally from needle to needle due to deformation of card.
  - Local AOT cannot be found using previous methods.
  - Card bending can be monitored from the force or tip contact characteristics of individual needle/group of needles.

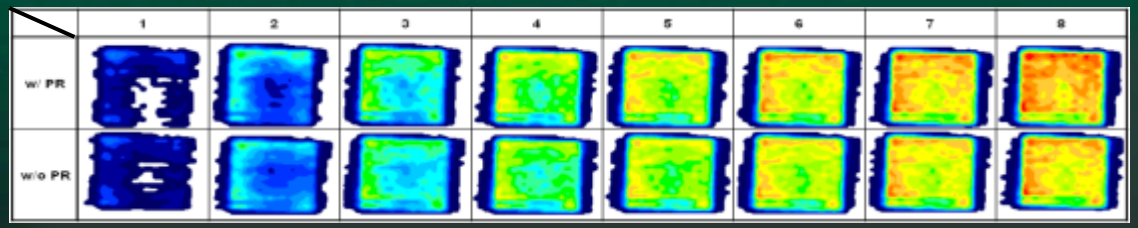


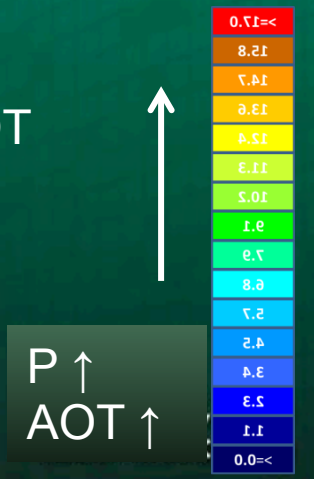
Measurement Methods

- **Method**
  - Conduction time lag
    - Simple and straight forward way to qualify the planarity of a card without using PCA.
    - The time until each channel begins conduction is recorded.
    - The z-position of each probe is proportional to the time lag.



  - Pressure Sensor Measurement
    - Pressure distribution of each DUT is proportional to local AOT
    - Larger pressure(pink/red) indicates higher AOT at the zone





Outline

- Overview/Objective
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I. Examining & Improving AOT/POT of a card

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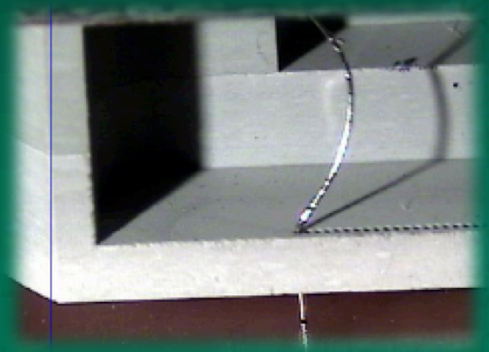
- Conclusion

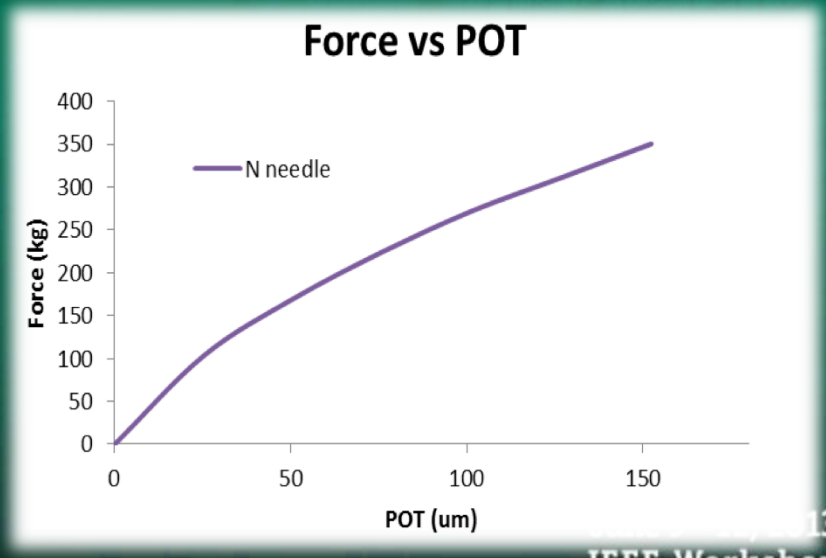
Single Probe

- **Card #1 Info:**
  - Teradyne J750
  - Needle Type: 3mil Flat
  - Pin Count N: 27xxx
  - DUT Count: 8
  - Planarity < 1mil

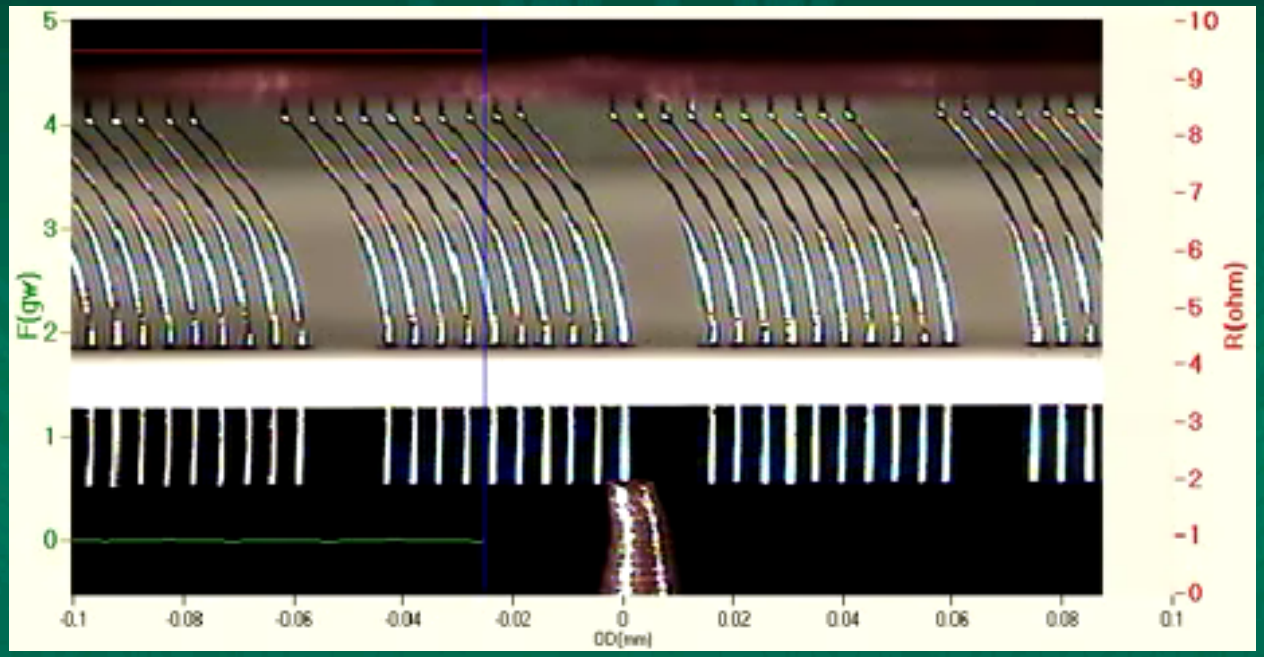


- **The force of a single probe is measured by Probe Analysis System for each OT.**

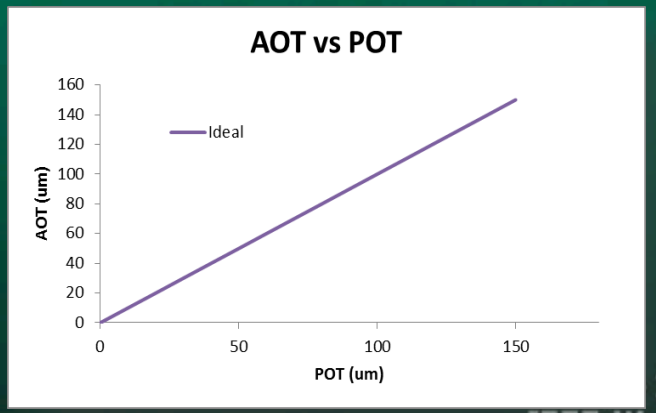
- **Ideally, the probe force can be as high as >300 kg for a fully populated probe head at 150um OT**



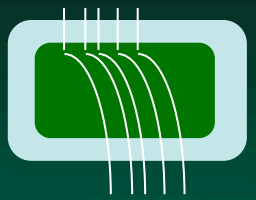
Single Probe



- For single needle measurement, AOT=POT as system deflection is negligible

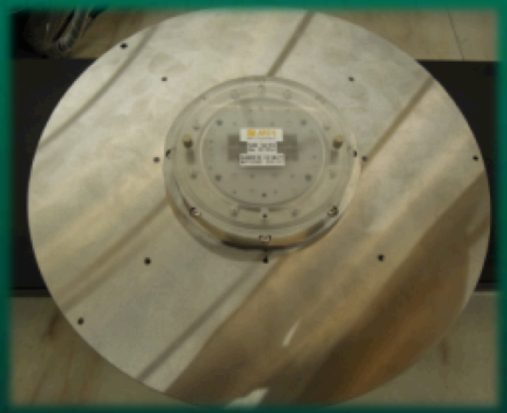


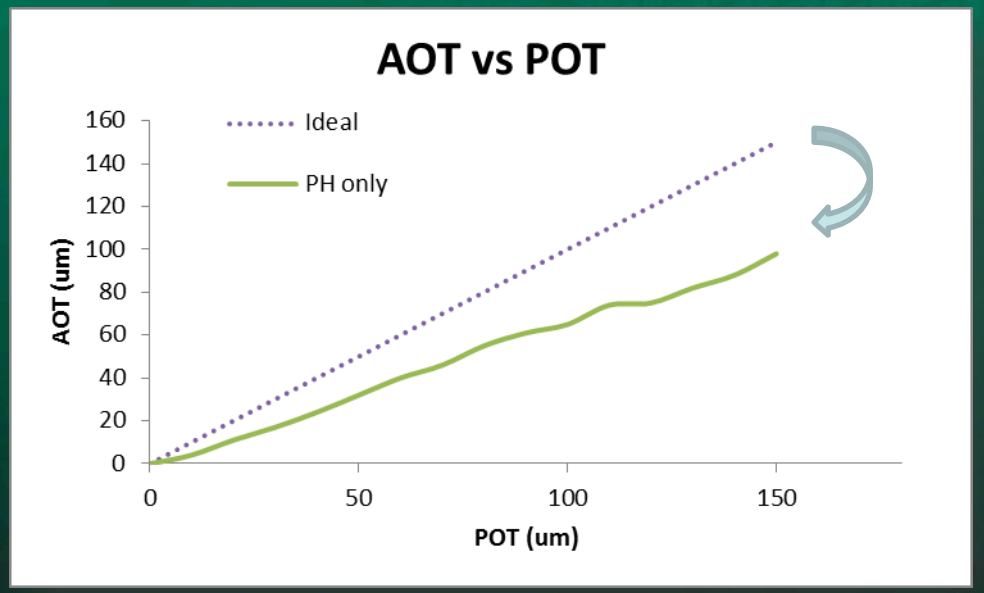
PH Only



- To obtain the AOT curve with the OD Checker for the PH only, a rigid steel PCB is used to minimize possible deflections.

- However slight bending still exists. Many other parameters affects the AOT as well. AOT will deviate from POT.





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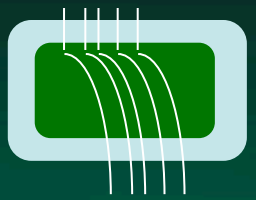
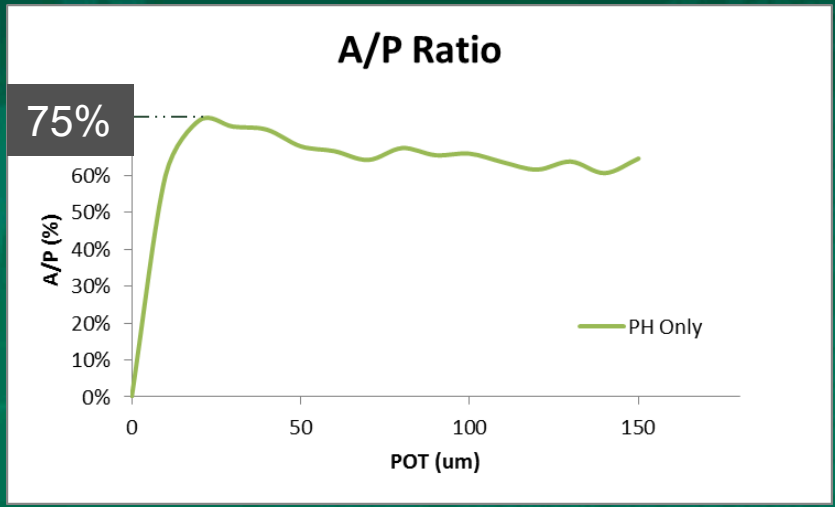


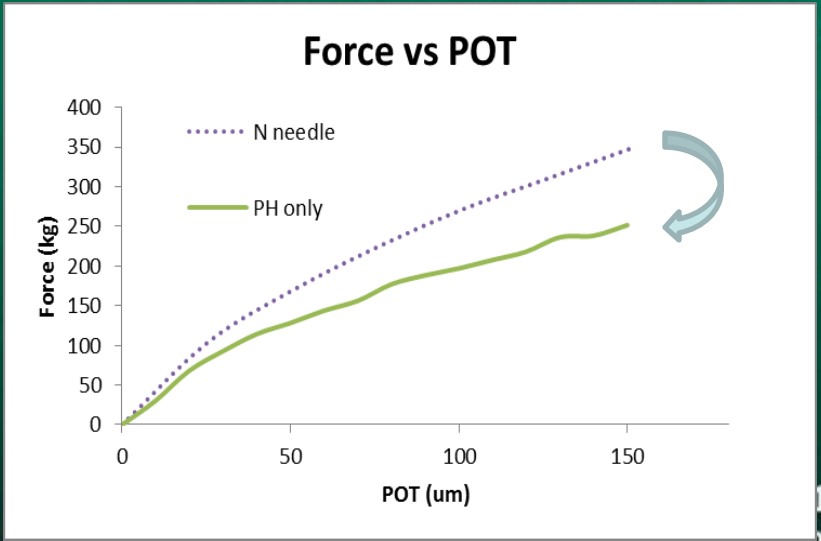
- A/P quickly builds and reaches max= 75%.

Planarity, variation in needle size and material uniformity are all factors leading to reduced max AOT.

- The ratio then decreases slowly as system deforms at higher force.

- Force drops from the ideal N needle.





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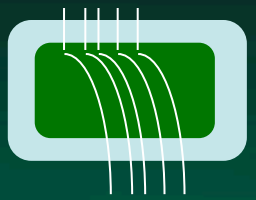
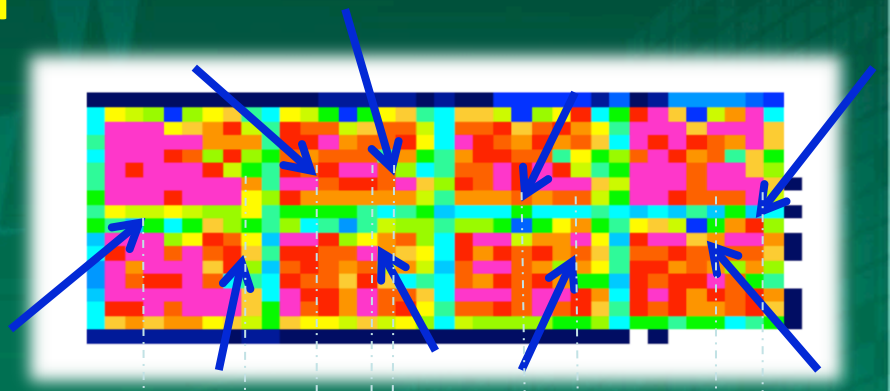
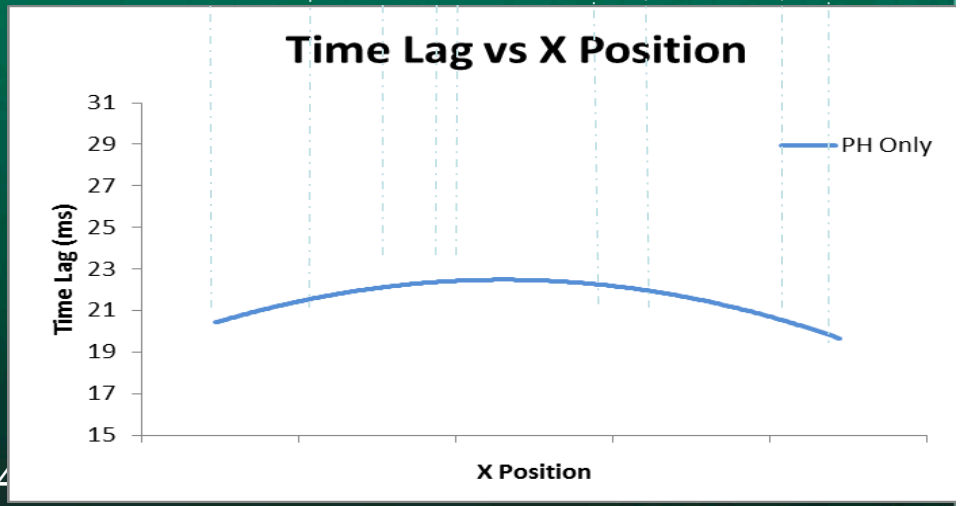


- P-sensor results show equally high forces exerted on each DUT at POT=150um



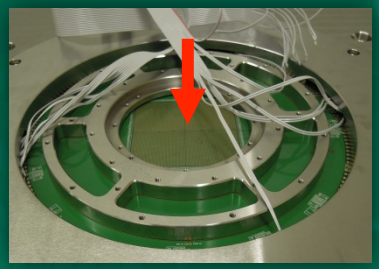
- With Real Time Recorder (RTR), profile of the needle tip is drawn by curve fitting the time lag results of selected channels along the x direction



- Tip planarity is rather flat at low OT

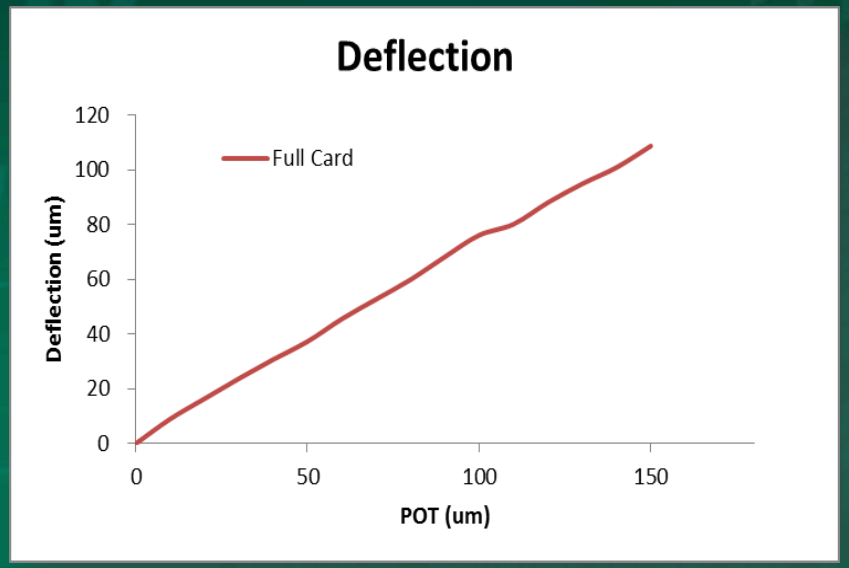
Typical Probecard

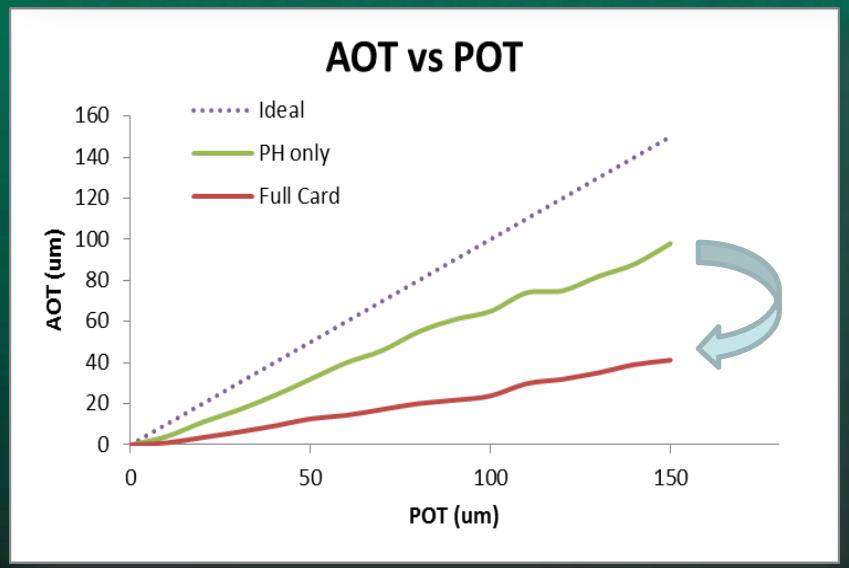
- Deflection is recorded with a detector at the center of the tester side of the card



- In a full card, deflection of space transformer, PCB and stiffener consume the program OT.

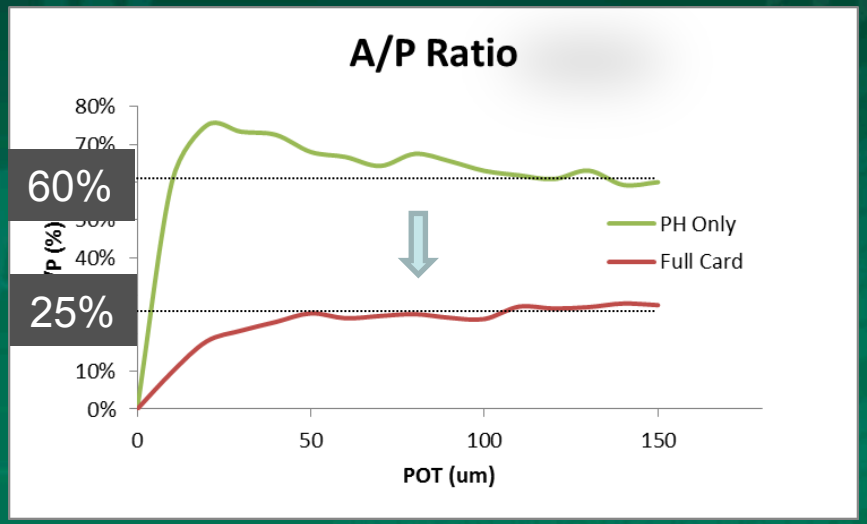
- The needles only take a fraction of the POT which leads to AOT drop.

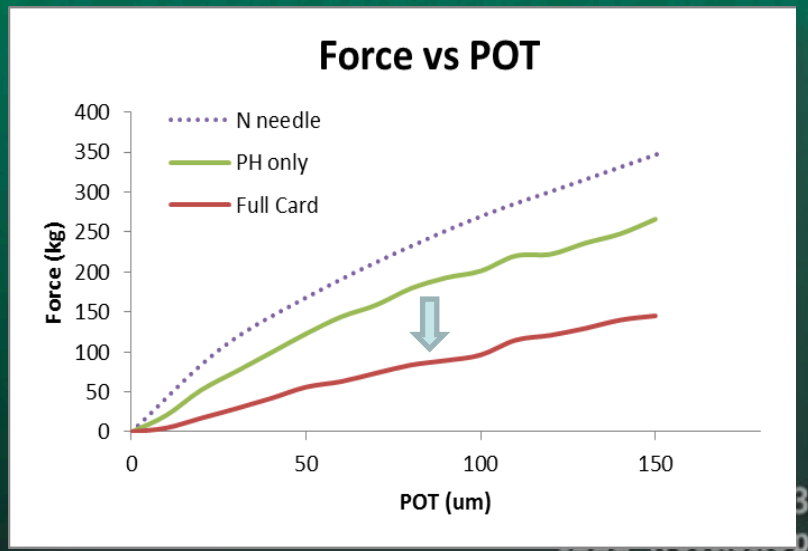




Typical Probecard

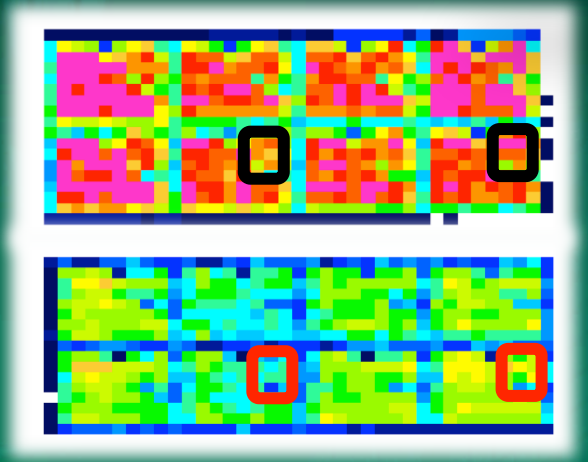
- A/P drops down to ~25% from the PH only value using a steel PCB
- PCB/ST/stiffener deformation takes >30% of the A/P
- Force lowers as a result of decreased AOT.





Typical Probecard

- **Tip pressure distribution shows:**
  - Lower overall pressure (POT=140um)
    → lower global AOT
  - Large inner and outer DUTs pressure differences: outer region touchdown harder and center softer
    → large local AOT differences



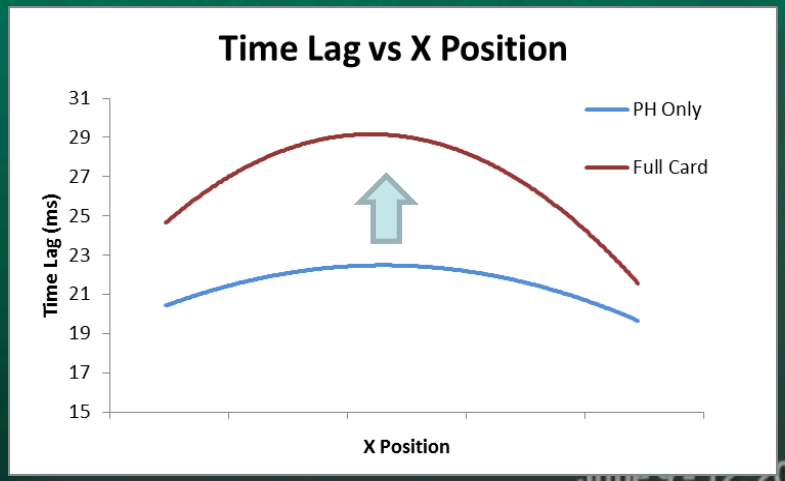
PH Only

ΔP=8%

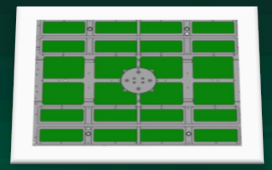
Full Card

ΔP=31%

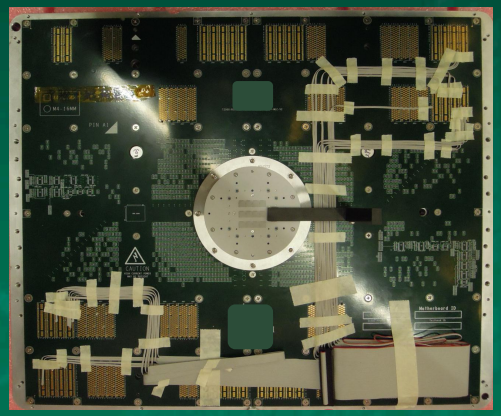
- **Card bending can also be observed from the tip even at the early stages of contact due to the force arise from the high pin count**



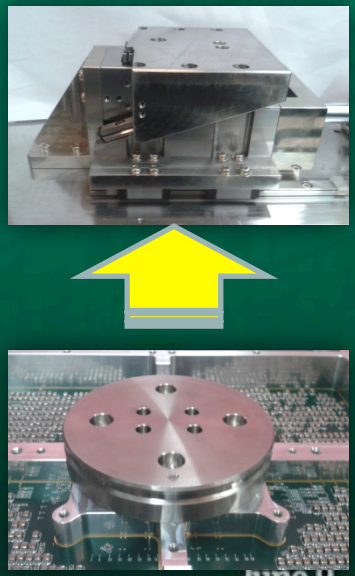
Direct Docking Card



- **Card #2 Info:**
  - T2000 RECT550 DD
  - Needle Type: 2.5mil Flat
  - Pin Count: 15xxx
  - DUT Count: 12
  - Planarity < 1 mil

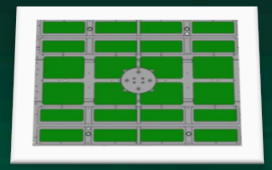


- **For this card, the main docking interface is the clamp head. Smooth docking between clamp head and bar is a major mechanical concern at the testing floor.**



- **Preliminary verification actions are required to check if the existence of a gap in between affects probing.**

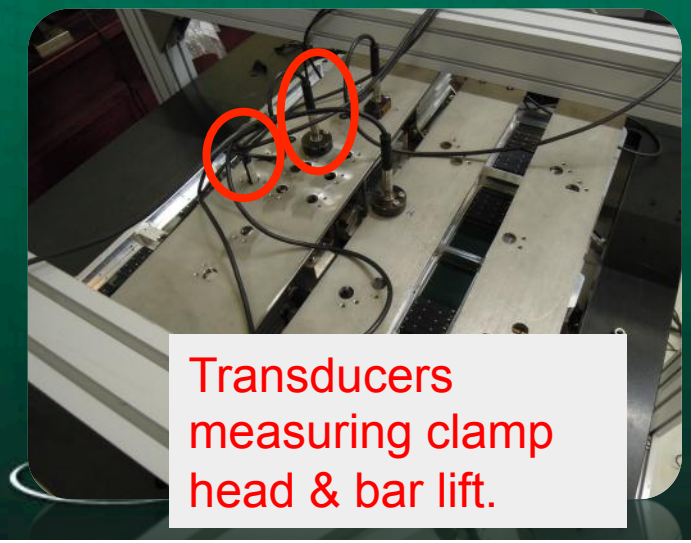
Direct Docking Card



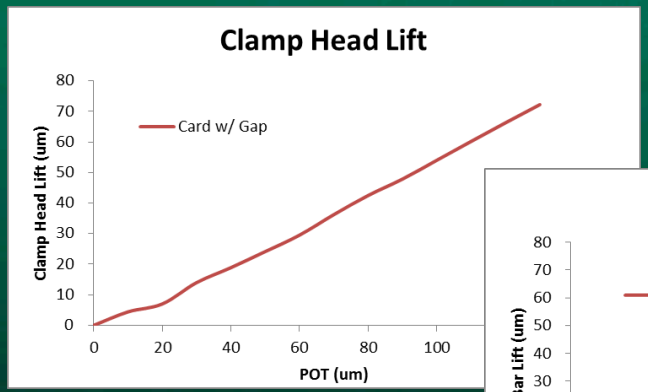
- A similar process can be repeated to measure all related parameters at high force using the DD Workstation starting with a configuration with gap.

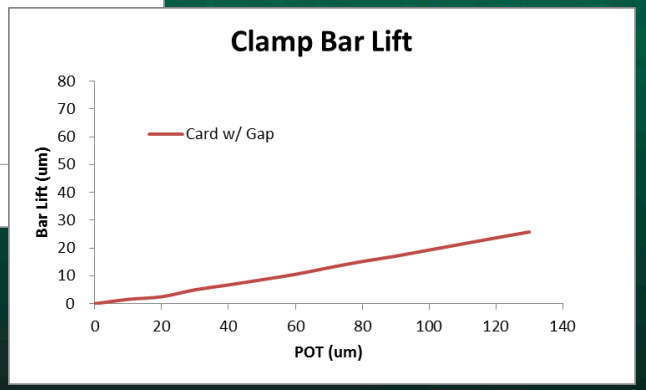
- When an OT is applied, card will deform and the clamp head will rise.

- The lift of the clamp bar is also monitored as system deflection.

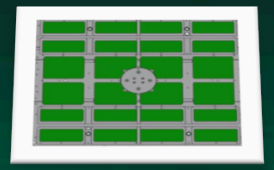


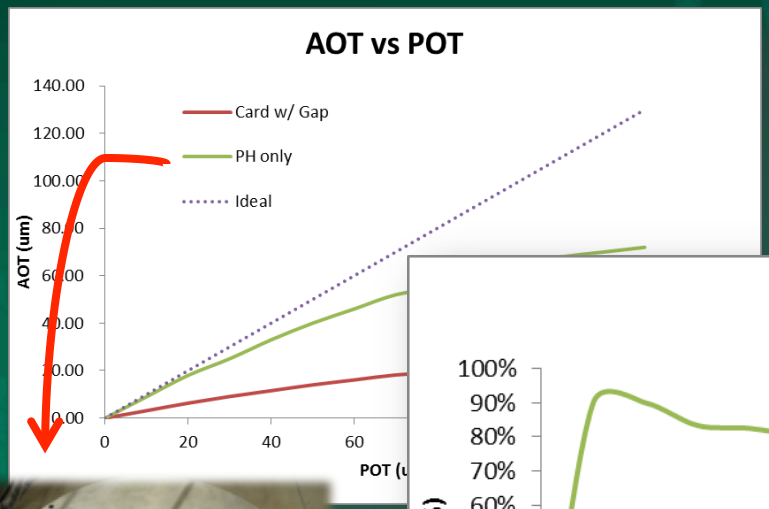
Transducers measuring clamp head & bar lift.

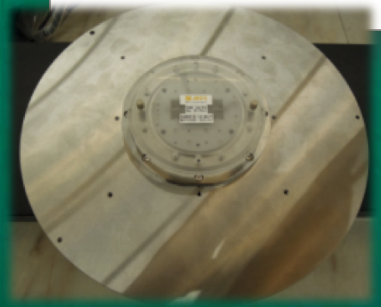


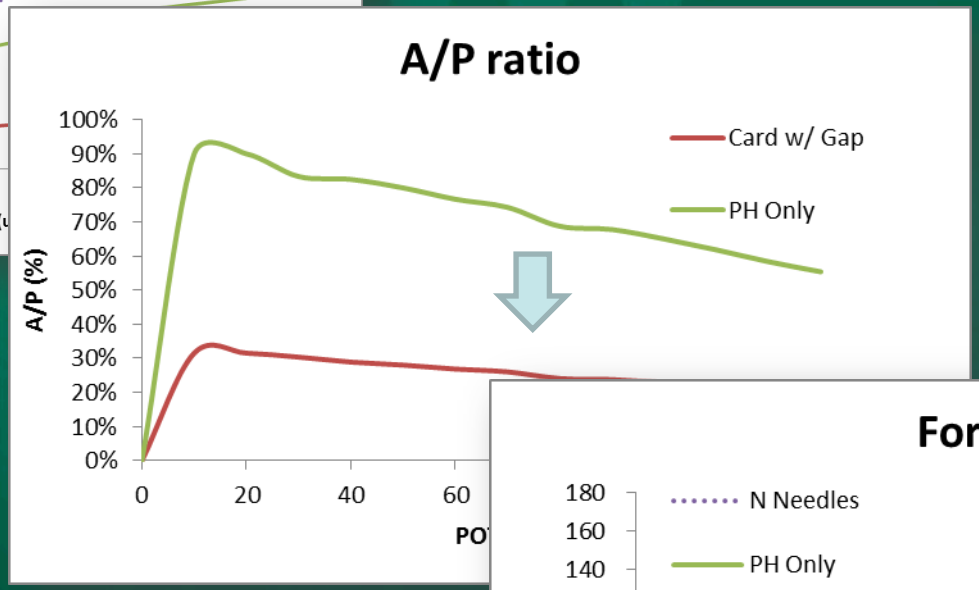


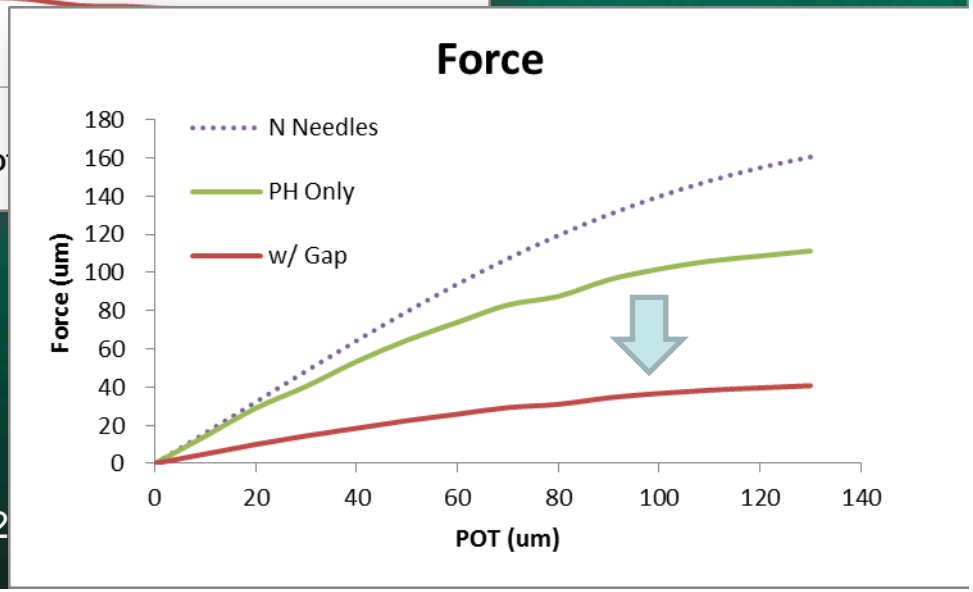
Direct Docking Card



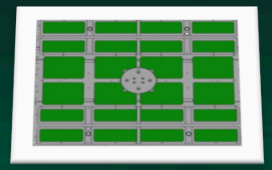




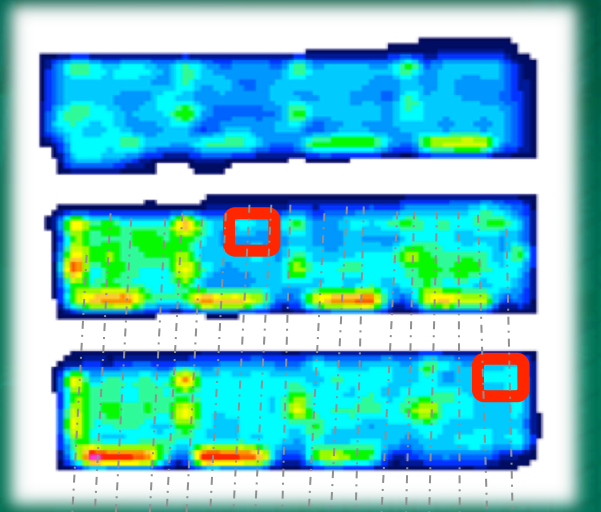




Direct Docking Card

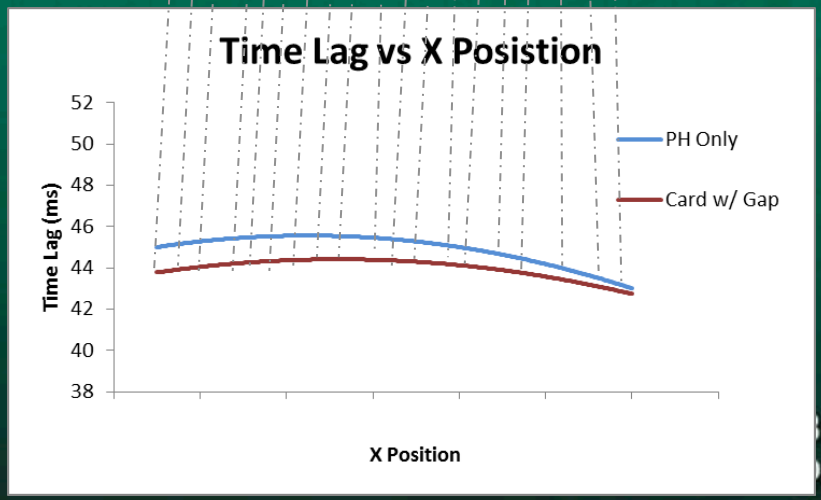


- Though slightly tilted, a similar center-outer difference can be found at POT=120um from P-sensor measurement, ΔP=33%



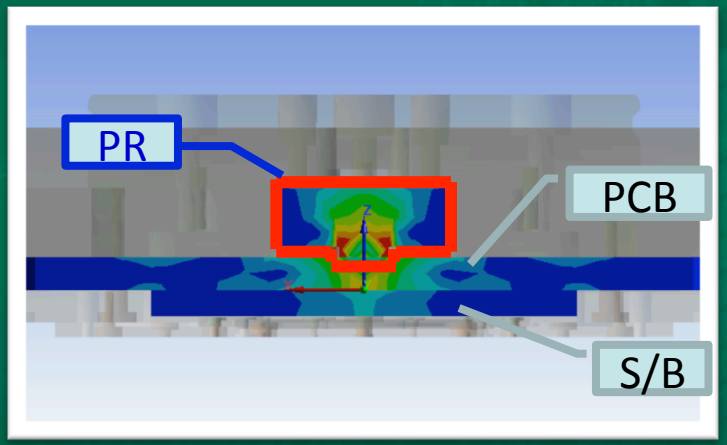
ΔP=33%

- A number of channels are selected to determine the time lag along x direction
- Card warpage at low OT is less significant as force is small at this pin count



FEA Analysis

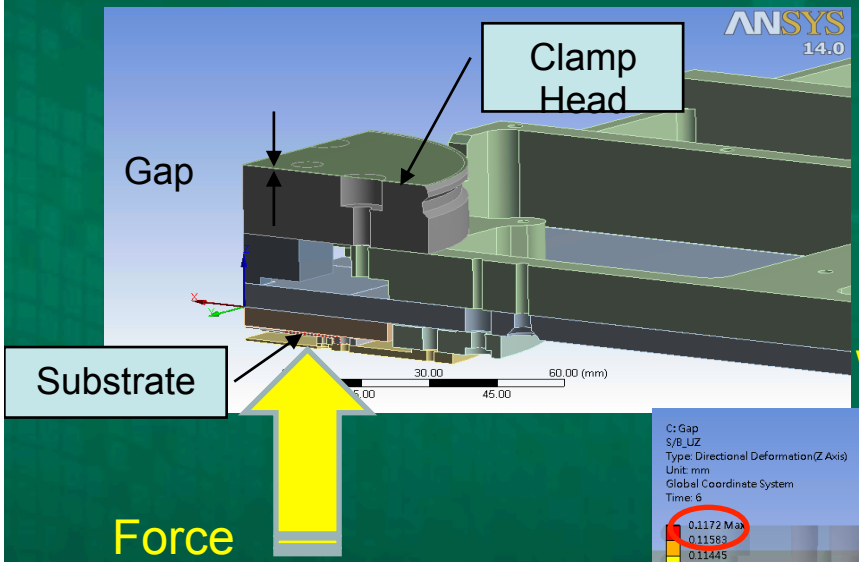
- **To approach a better design, we return to ANSYS simulation**
- **Essential components are introduced for improved A/P:**
  - Device #1: Preload Block at the center of probe card



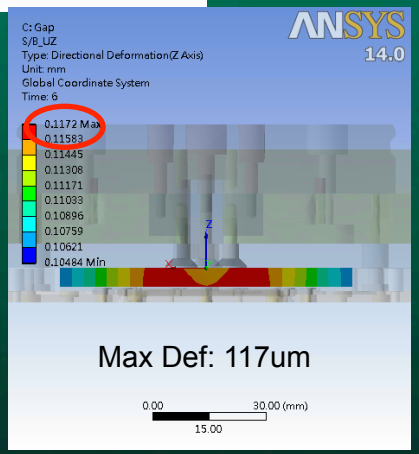
  - Device #2: Gap eliminated between clamp head & bar

Improving the Design

- As an simulation example, the substrate deformation is directly compared at force=150kg between DD with and without gap above the clamp head.

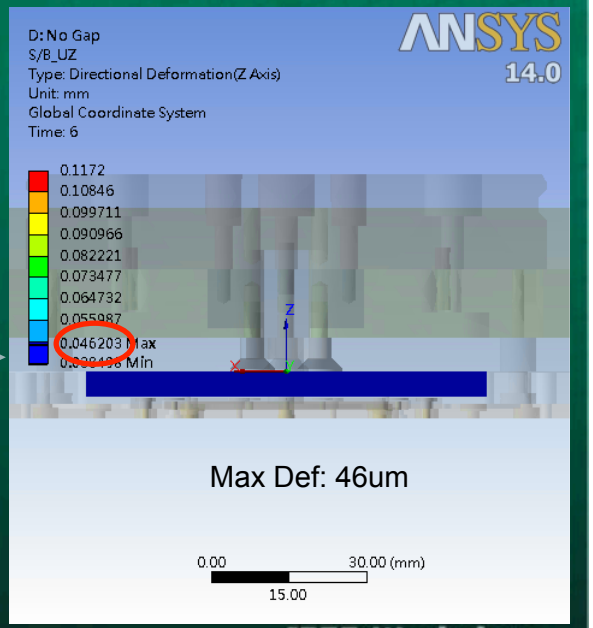


w/ Gap



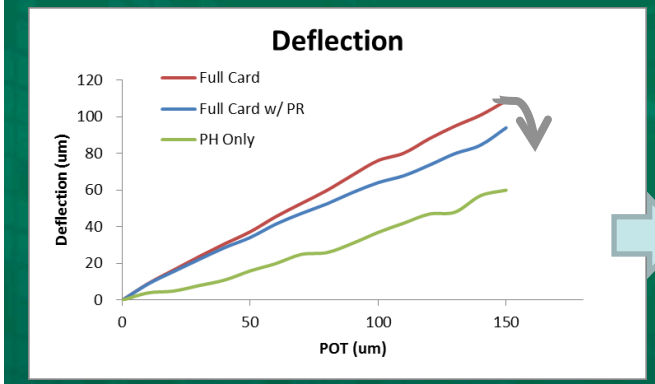
Substrate deformation reduced by 61%

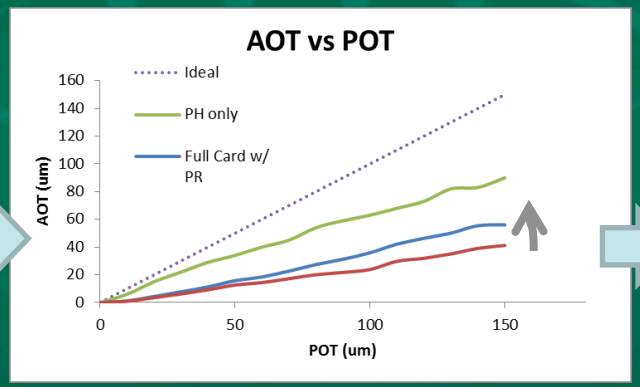
w/o Gap

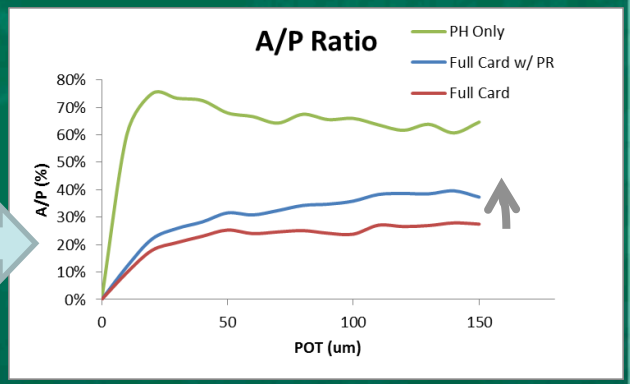


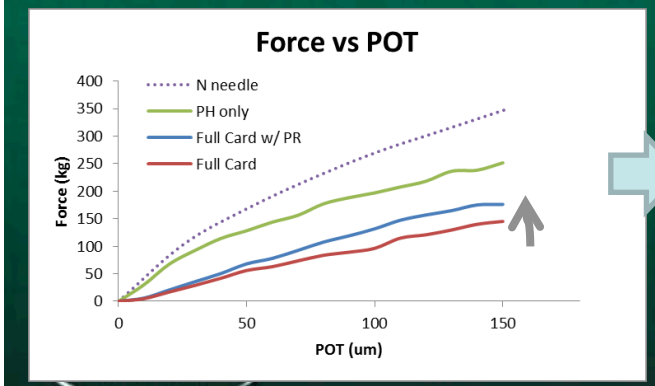
Further Verification

- **Once again we go back to our tools and check if improved…**
  - Device #1: w/ or w/o **PR**



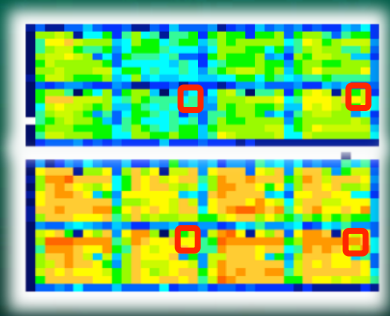




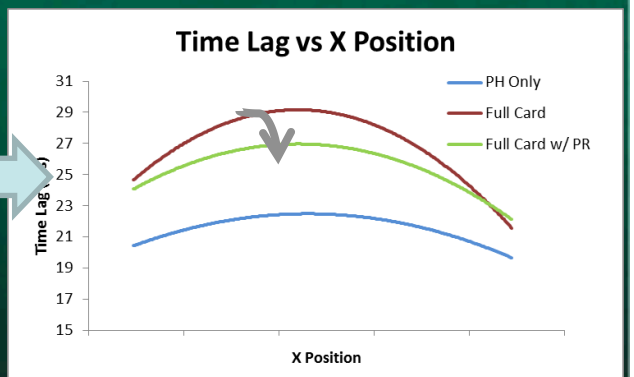


w/o PR

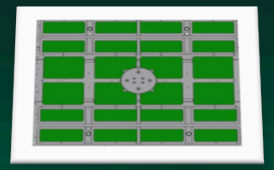
w/ PR



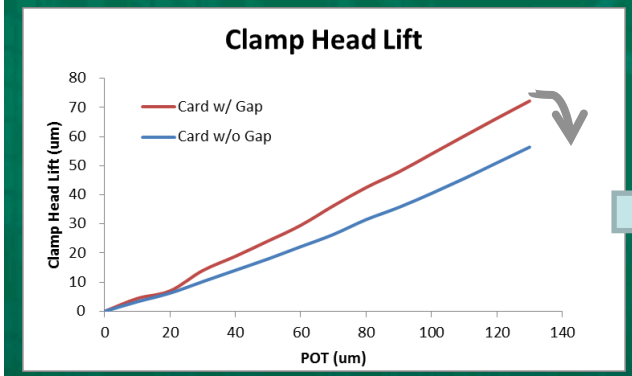
ΔP: 31% -> 18%

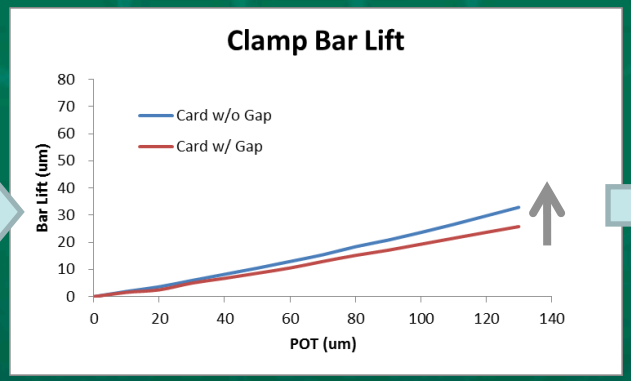


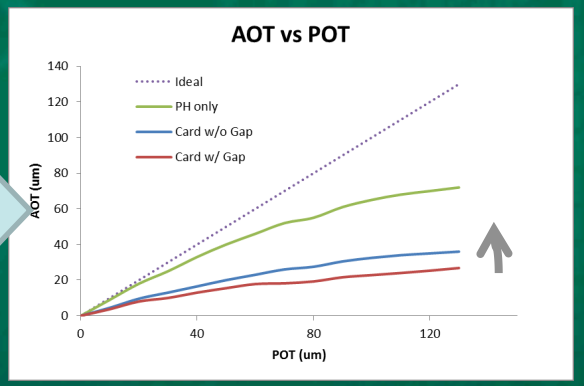
Further Verification

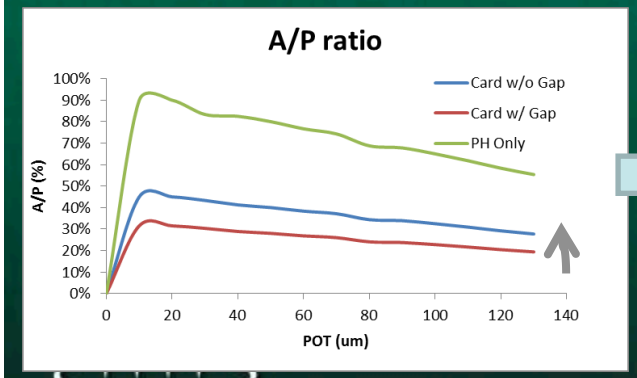


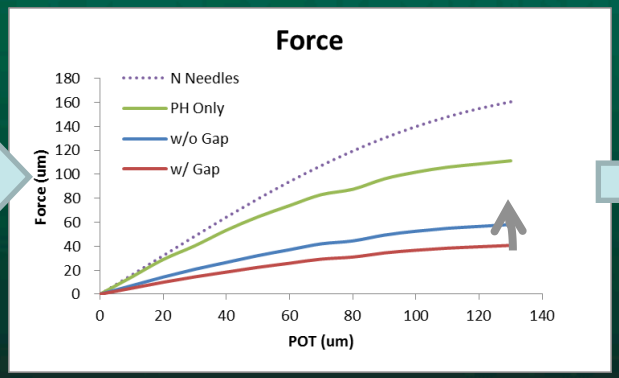
- **Once again we go back to our tools and check if improved…**
  - Device #2: w/ or w/o **GAP**

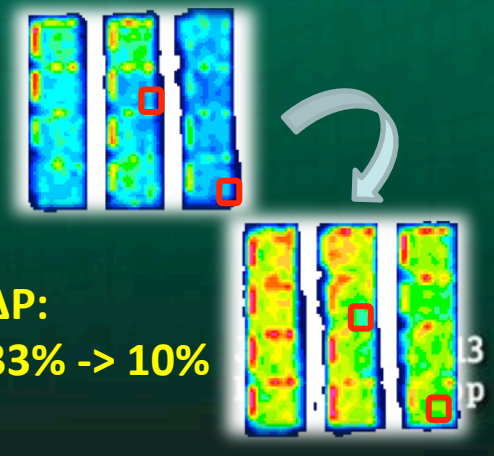






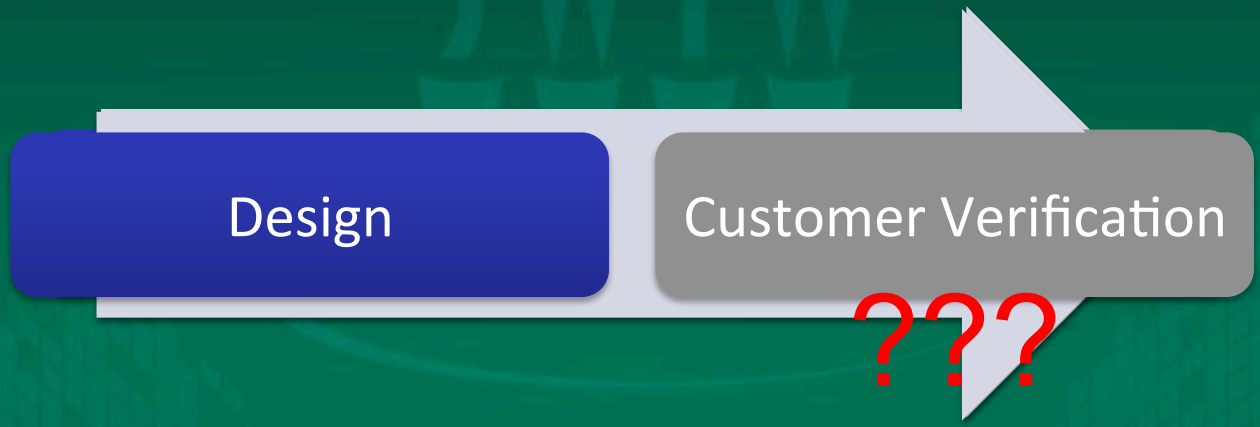




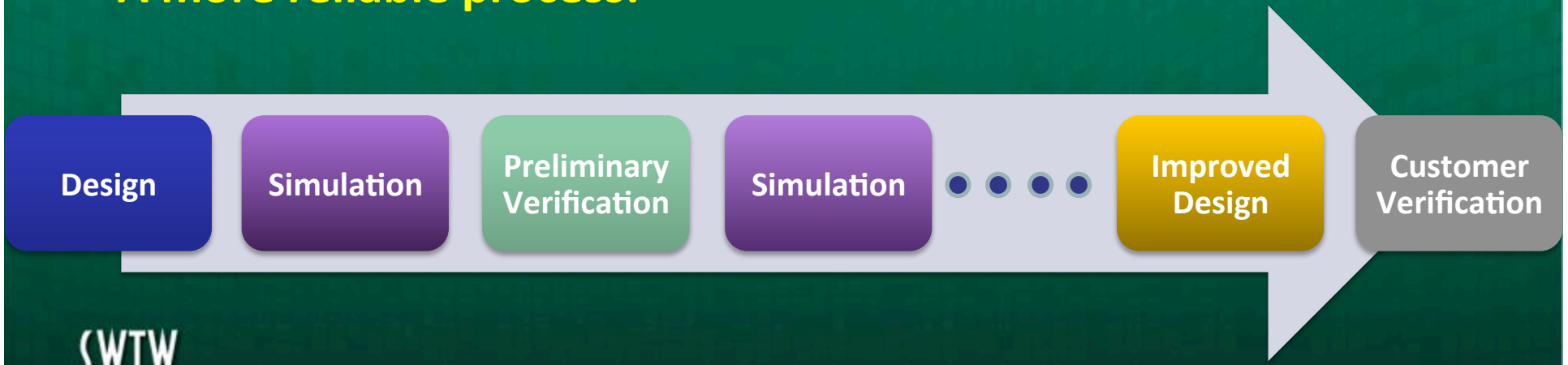


Design Practice Change

- **Typical design process:**



- **A more reliable process:**



Outline

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From Global to Local…

- To enhance the stiffness of the probecard, a larger/thicker/ fully-covered stiffener can be introduced.
- This is a global point of view.

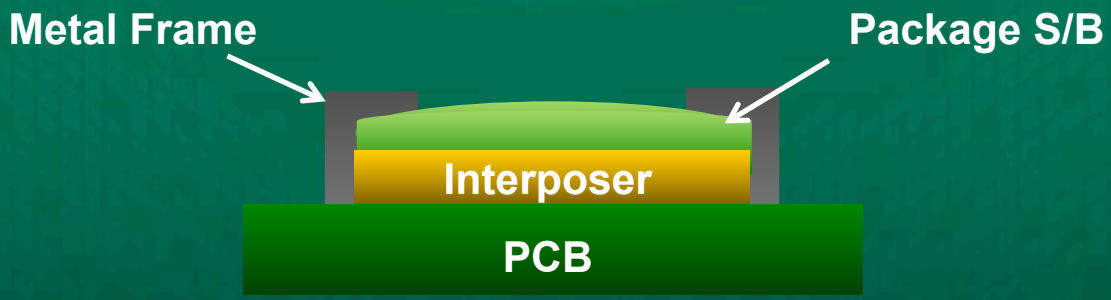
- But can we build a probe card that is intrinsically stiffened?

Indeed!!

- By enhancing localized structures, mechanical performance and reliability can be significantly improved.

Package S/B

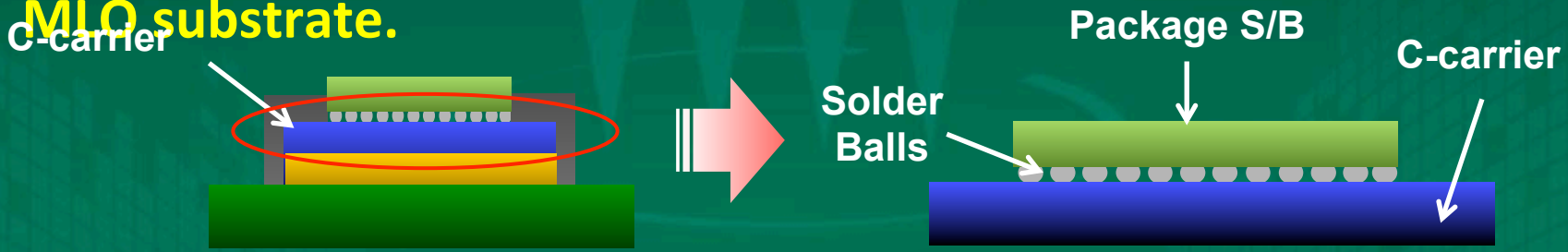
- For mobile devices, package S/B thickness can be as thin as: 0.2~0.4 mm
- For CP/FT interchangeability, an interposer is used and the preload applied bends the MLO.
- Due to restriction of the metal frame, the inner section is pushed up higher than the outer part and warpage propagates to the needle tip.

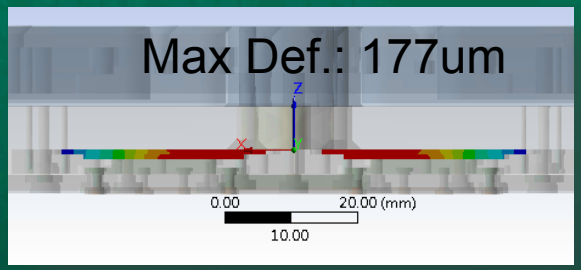


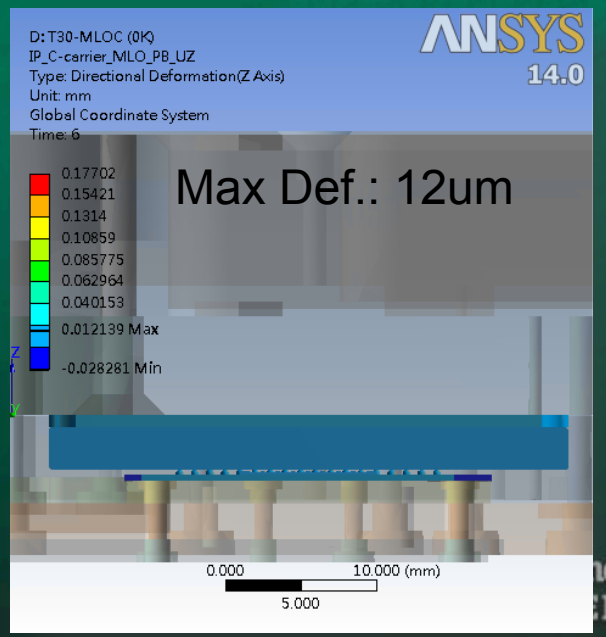
- If stiffness of S/B is not sufficiently enhanced, the contact quality drops and there will be delay in conduction.

MLOC

- The new MLOC design could considerably improve the situation.
- The high stiffness of ceramic carrier compensates for the weak MLO substrate.



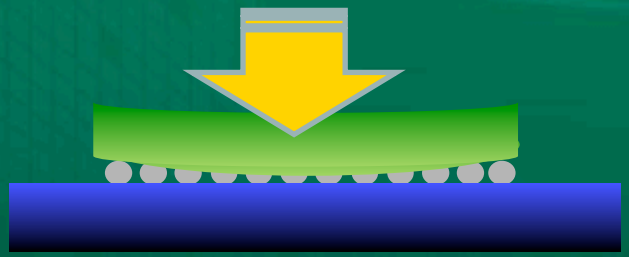


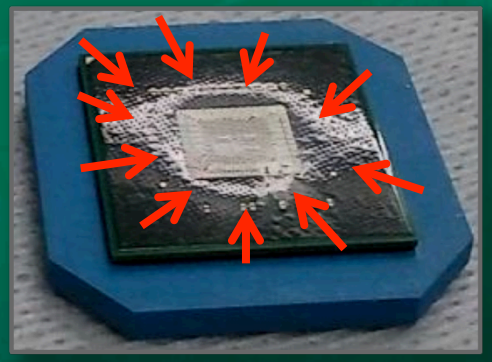


Deformation reduces from 177um to 12um using MLOC

Marathon Test

- However, by ~200k TDs, the S/B begin to warp seriously towards the C-carrier, especially the C4 area.
- The C4 area has to sustain all probing forces and after continuous compression, solder balls flatten and S/B bends. This leads to bad planarity & reduced localized AOT.

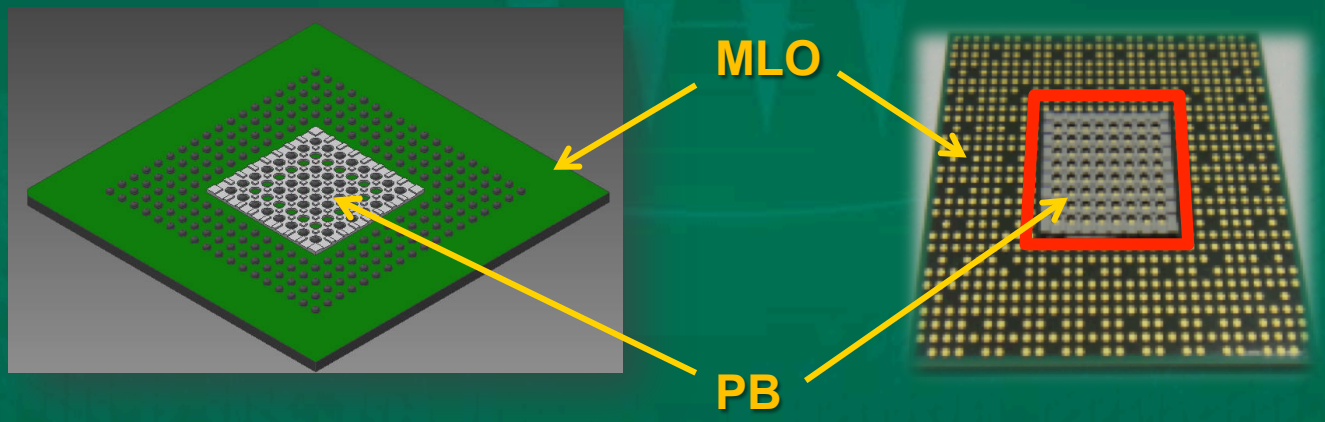




- Deformation exacerbates especially for high payload devices.

PB (Pegboard)

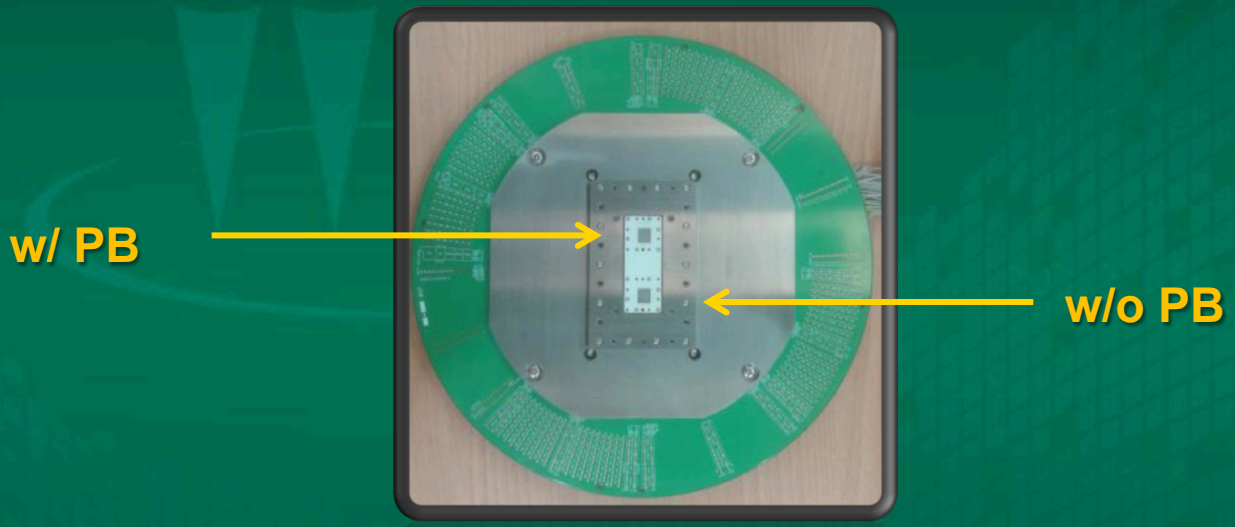
- To further suppress warpage for longer lifetime, additional medium can be added in between the solder balls for reinforcement – Pegboard (PB)



- The C4 solder ball regions are protected from direct compression.

Measuring Warpage

- Preliminary verification was done to monitor the warpage for both MLOC and MLOC+PB using a dual site device

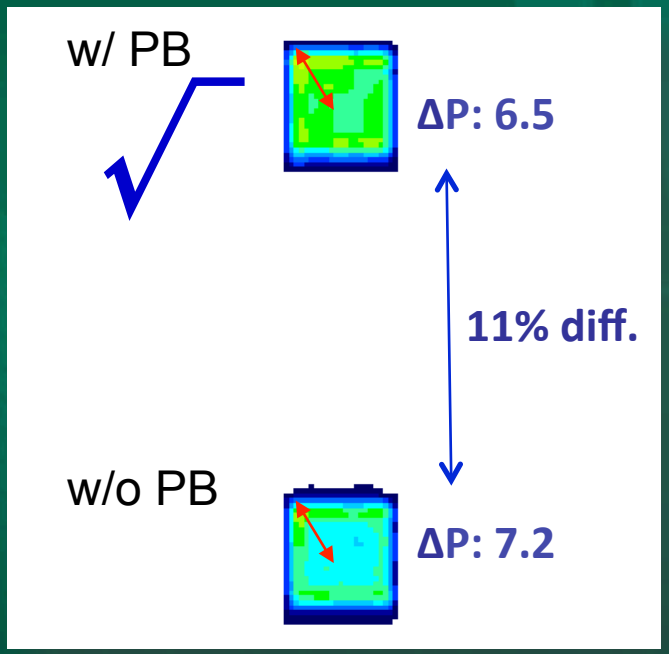


- 2 experiment sets: before and after 200k TDs
- Pressure distribution of each DUT is compared.

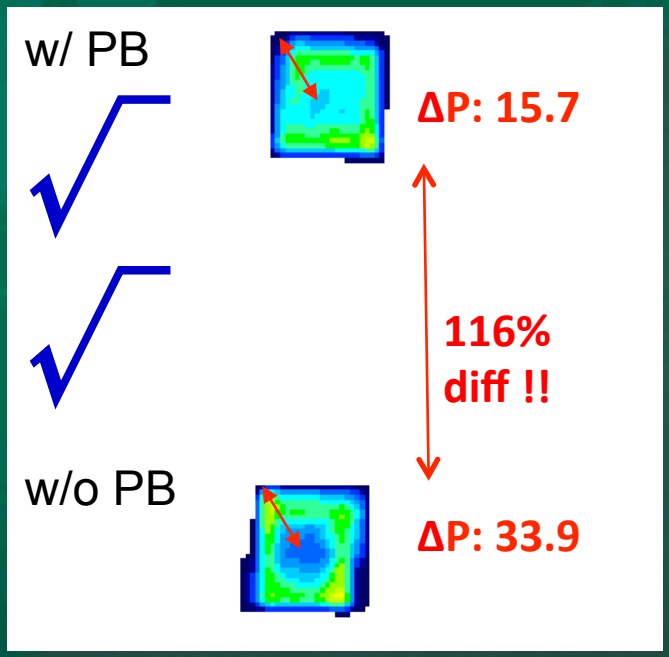
Measuring Warpage

- At POT= 140um:

Before 200k Touchdowns



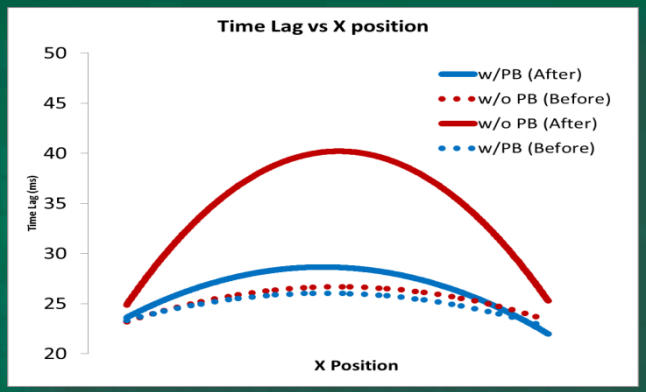
After 200k Touchdowns

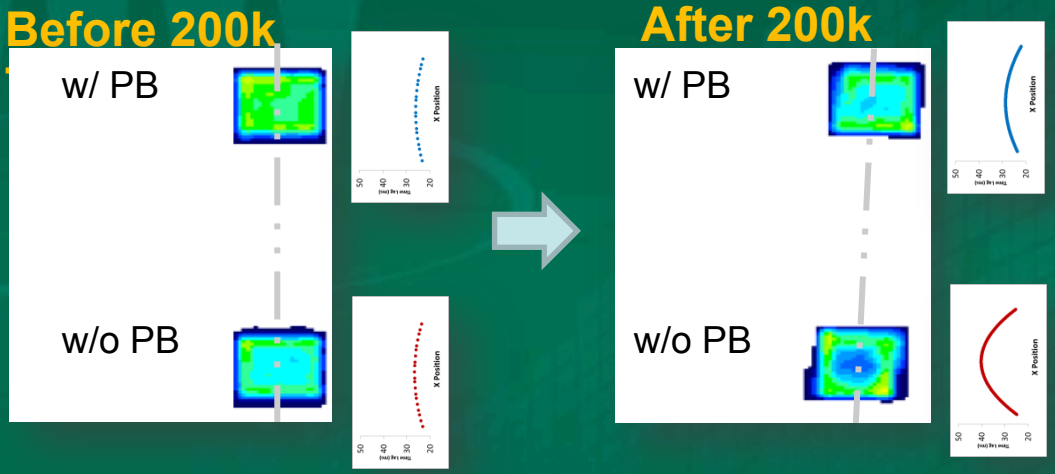


- DUT w/ PB provides slightly larger force: <u>better global AOT</u>
- DUT w/ PB has smaller pressure difference: <u>less local AOT diff.</u>

Measuring Warpage

- Taking advantage of RTR time lag measurement:





- From the verification process, the importance of PB is discovered and developed.
- Apparently, using PB suppresses substrate deformation and thus increases localized AOT

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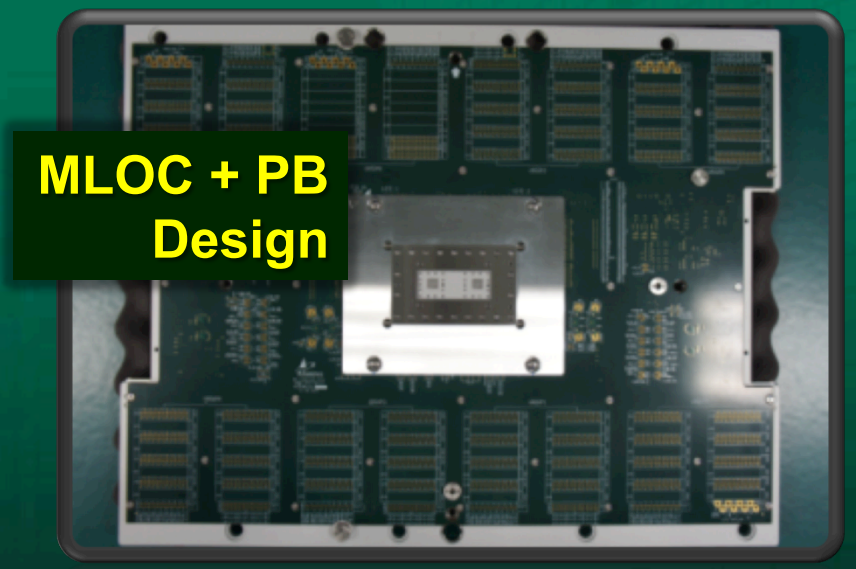
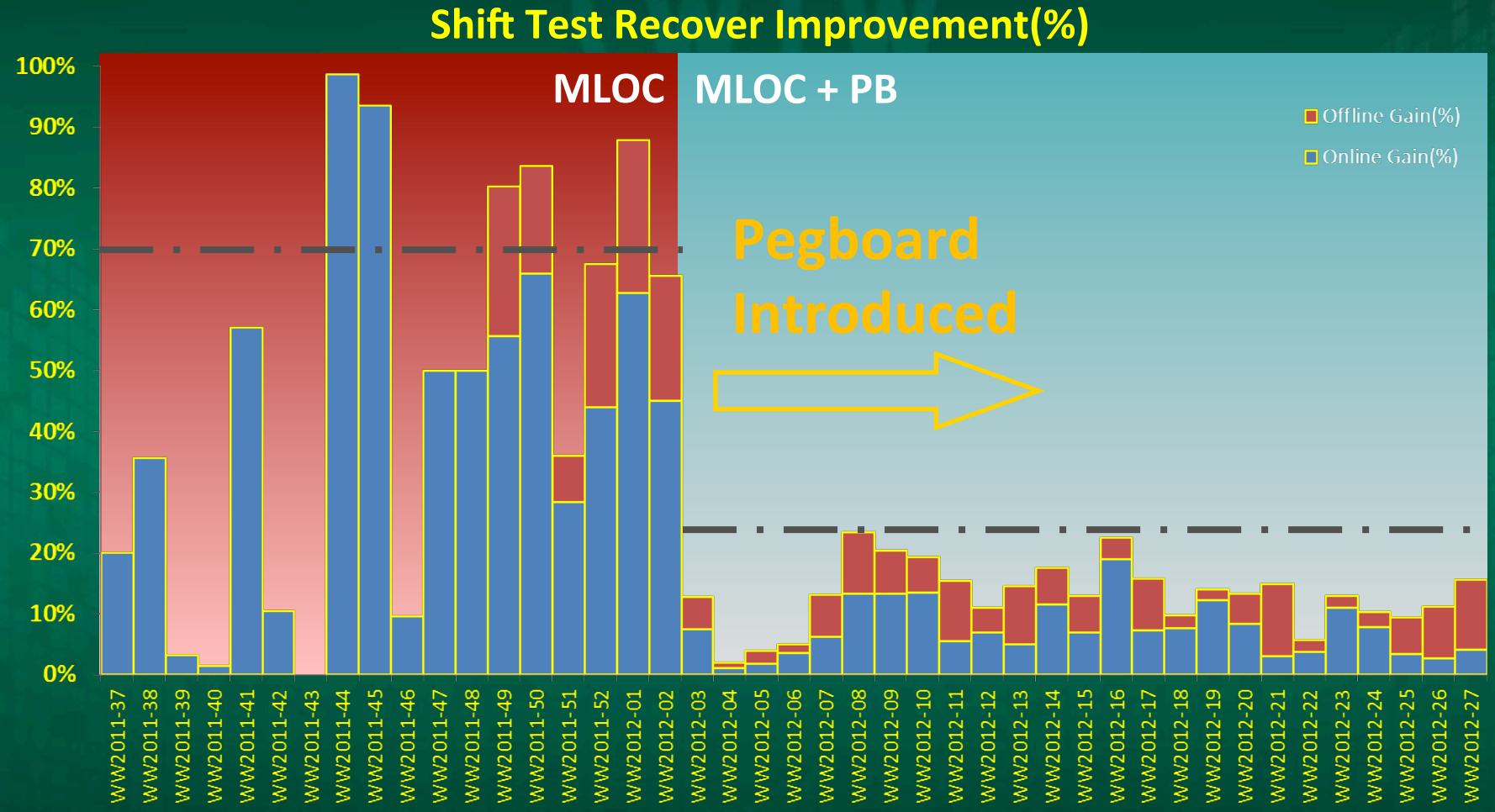
Customer Site Validation

- **New design is proven to be good at customer site**
  - Card #3 info:
    - Advantest 93000 DD
    - Needle Type: 4mil Flat
    - Pin Count: 3xxx
    - DUT Count: 2
    - Planarity < 1mil



Customer Site Validation



✓ **Need for retest plunged by ~50 % after using PB.**

Conclusion

- **In-house verification has to be included in the design practice.**
  - Using dedicated instruments, key variables can be monitored.
  - Mechanical deformation issues can be accounted for before shipment if in-house verification is conducted.

- **Localized stiffness can be enhanced.**
  - MLOC implemented for thin S/B robust design
  - Pegboard introduced to extend probe card lifetime

Future Studies

- **High/Low temperature studies to be continued.**
  - Force distribution at 150/-40°C
  - A/P change
  - Localized behavior differences
  - And more…

Acknowledgement

- Thanks to all MPI VPC R&D members for your support.
  - Zach Hsieh
  - Jacky Lee
  - Jack Hsu
  - Weyth Lee
  - Ryan Kuo