SWTEST
PROBE TODAY, FOR TOMORROW
2024 CONFERENCE

Towards Ultra-High Pin Count Probe Card for high end logic devices

TECHNOPROBE

ADVANTEST®

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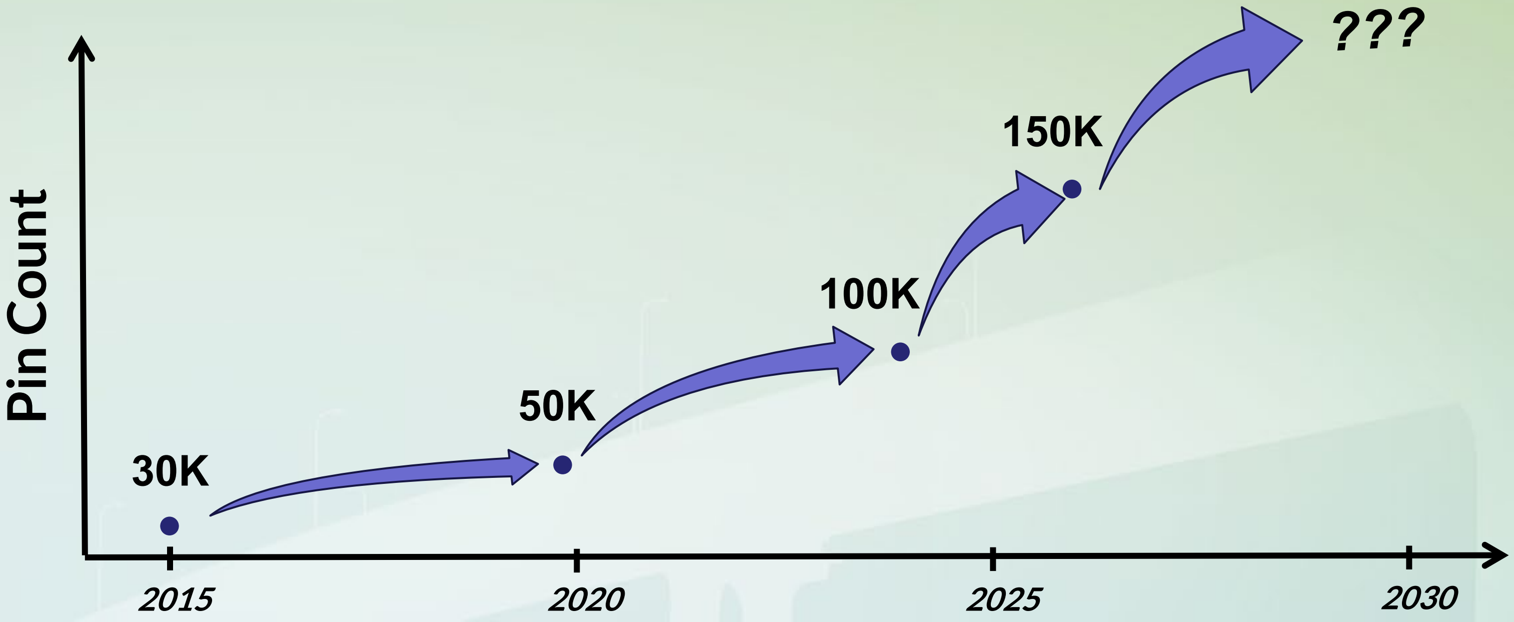
Outline

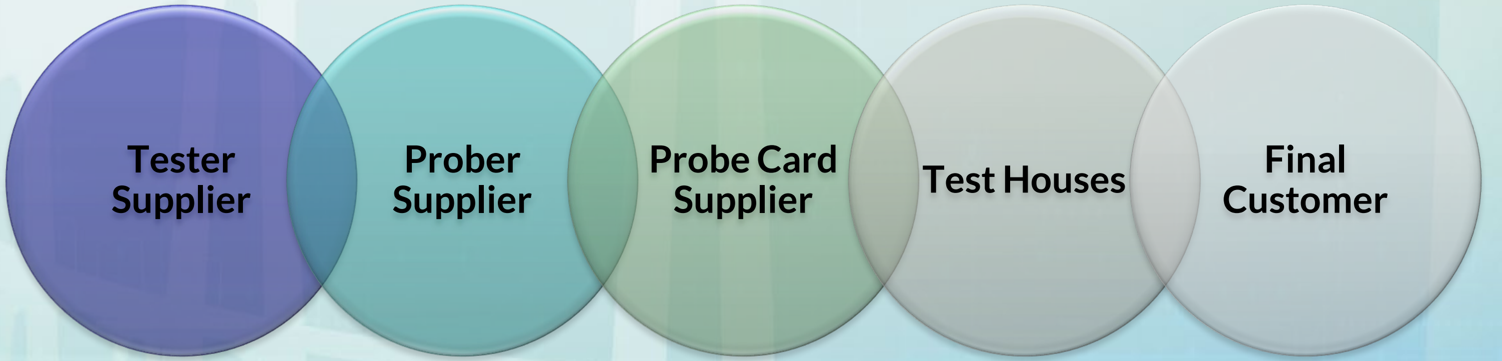
- Introduction
- Goals
- Ultra High Pin Count Test Vehicle
  - Probe Card Details
- Deflection Study:
  - Experimental setup & results
  - Simulations agreement with experimental data
- Upgrades on Probe Card Analyzer (PCA)
- Conclusions
- Follow-On work

Challenges

- The ability to increase pin counts is one of the main challenges to overcome in the advanced vertical probe card industry.



- It requires a strong collaboration between every contributor in the wafer testing supply chain



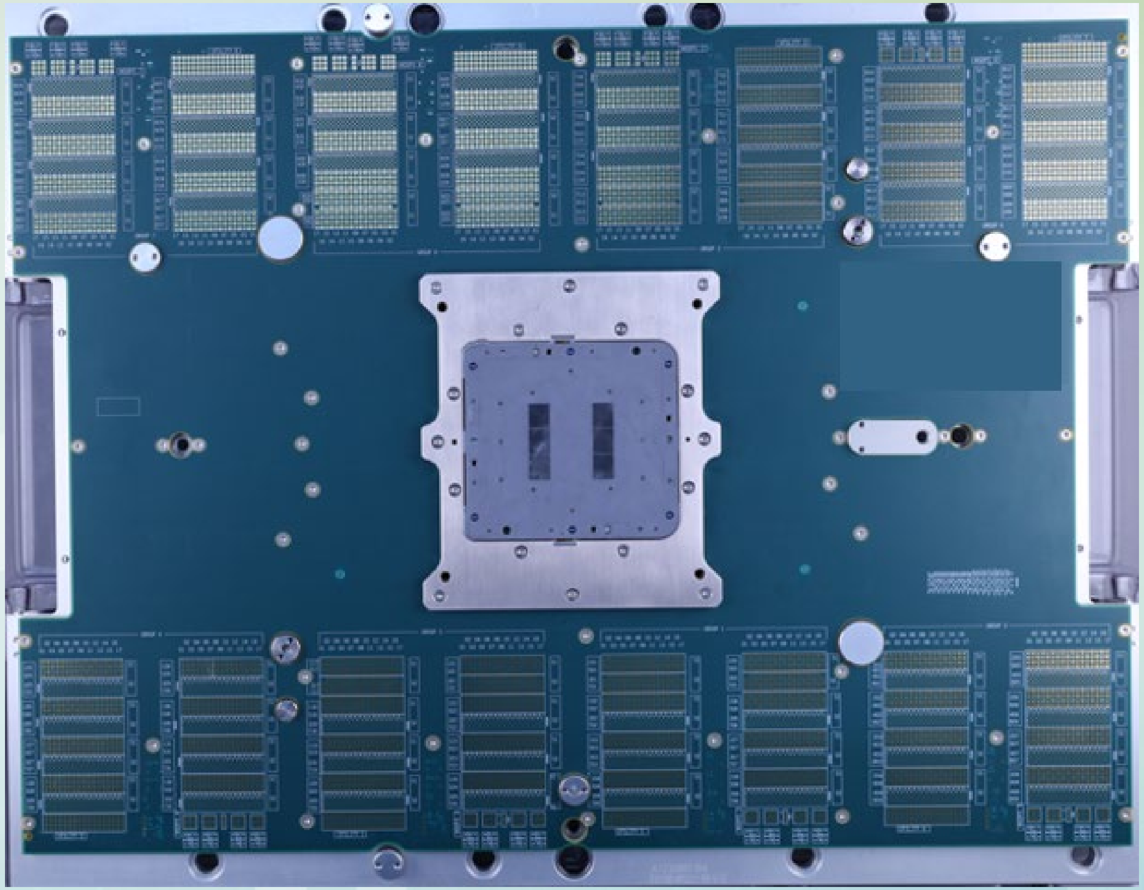
Goals

Ultra-High Pin Count Probe Card

- How to optimize Probe Card structure and technology to increase pin count?
- What is the capability of the entire test cell with high load probe card?
- How to measure deflection?
- Which is the main contributor to deflection?
- What can be simulated?

Ultra High Pin Count: Probe Card Details

ULTRA HIGH PIN COUNT PC	
Pin Count	94962 pins
Probe Technology	UXS: Low Force & Extra Short probes
Total Probe Force	167 Kgf
Parallelism	6 DUT
Array Size	X =39,2mm ; Y=43,6mm
Array Area	1704,6 mm^2
Testing Platform	V93K Digital Bridge Beam



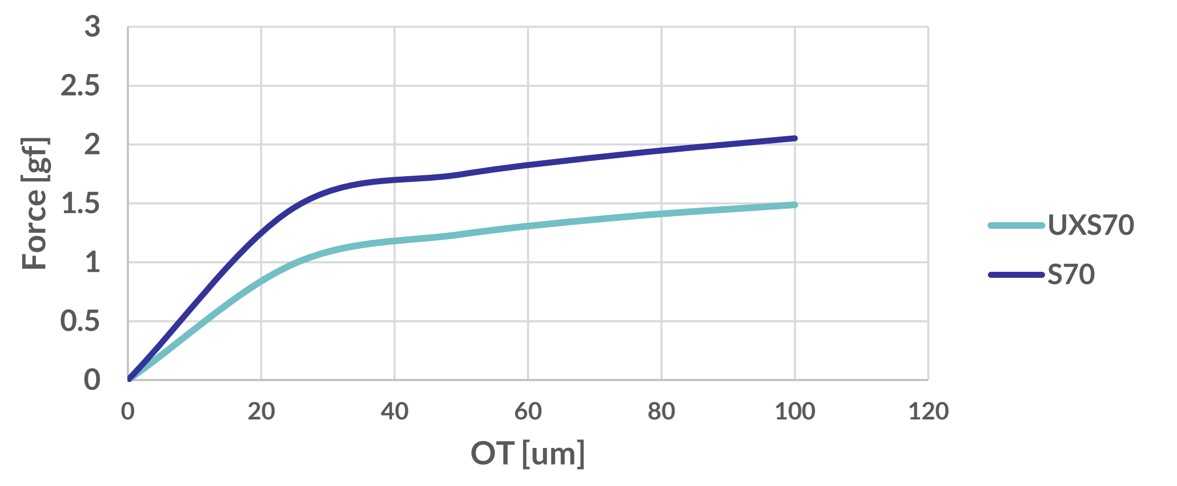
Ultra High Pin Count: Probe Technology

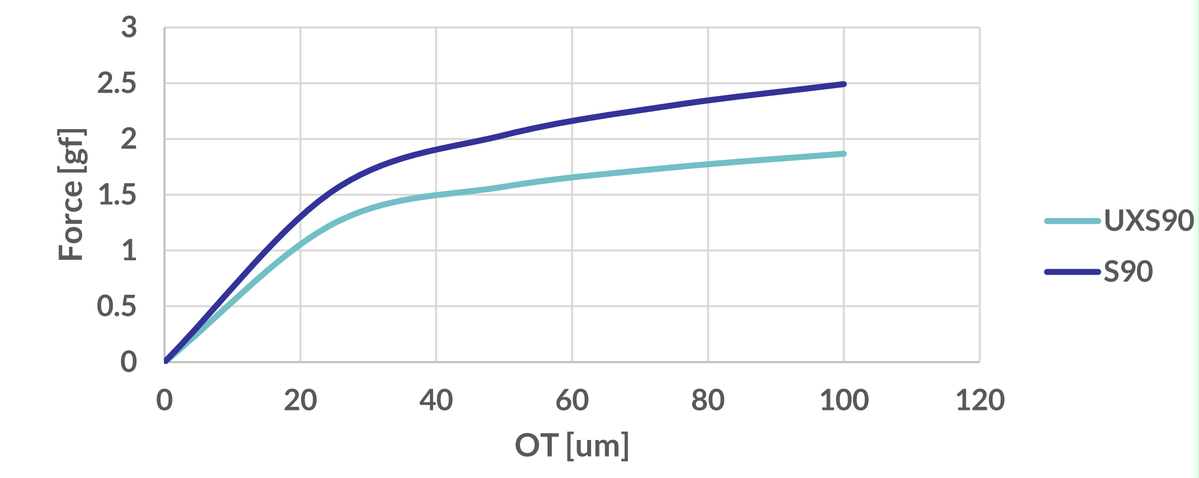
With ultra short and low force needles (UXS family) we can achieve remarkable improvements in terms of:

- Force and Deflection reduction
- SI performance
- PDN performance

	S family	UXS family
Deflection	POR	Improved ↑
SI		Improved ↑
PDN		Improved ↑
CCC		Same as POR ↔

S70 vs UXS70	S90 vs UXS90
Force (at 75 um OT) = 1.9gf (S70) vs 1.4gf (UXS70)	Force (at 75 um OT) = 2.3gf (S90) vs 1.8gf (UXS90)





Considering 95K pins PC, the implementation of UXS leads to a 20% of total load reduction

Ultra High Pin Count: Probe Head

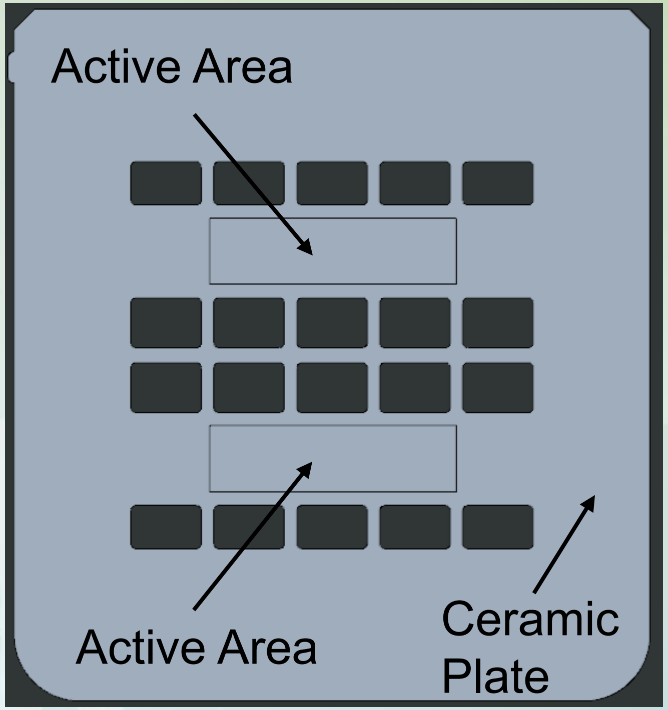
Probe Head mechanical structure has been customized based on FEM simulation results.

- In FE simulations we calculate the ceramic plate displacements [µm] and ceramic Failure Index (FI) when the Probe Head is subjected to Probe Loads.

- FI is defined as the ratio between the calculated state of stress in the material and the material resistance limit.

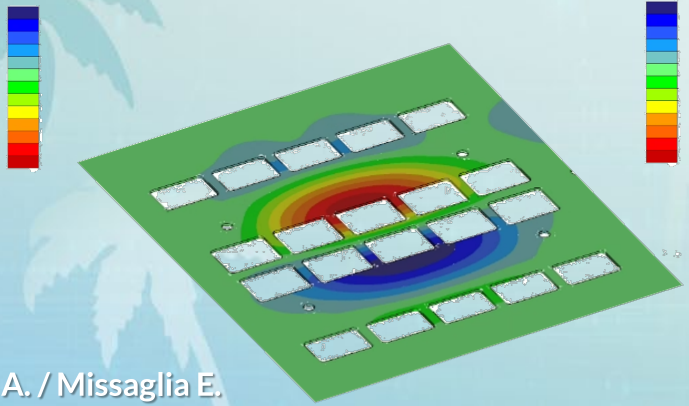
$$FI = \frac{State\ of\ Stress\ in\ ceramic\ plates\ [MPa]}{Material\ Stress\ Limit\ [MPa]}$$

Double skip configuration

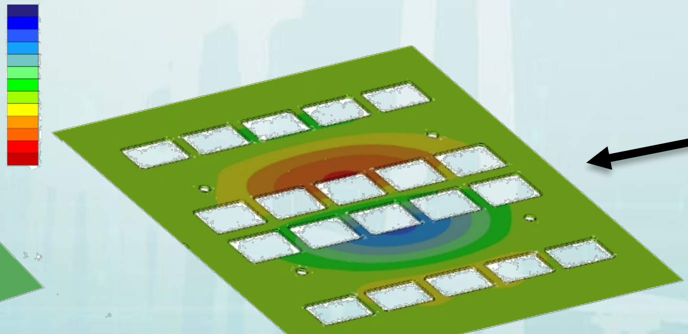


Example: Plate Vertical Displacement [µm]

POR (Probe S Series):



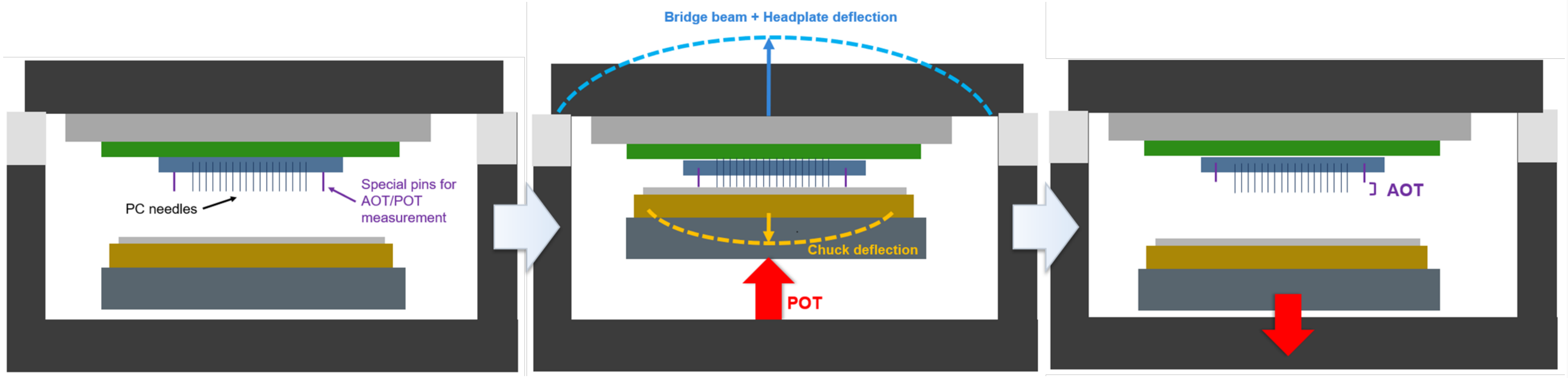
Improved:(Probe UXS Series):



The implementation of UXS leads to a 20% reduction of Ceramic Plates Vertical Displacements and Failure Index

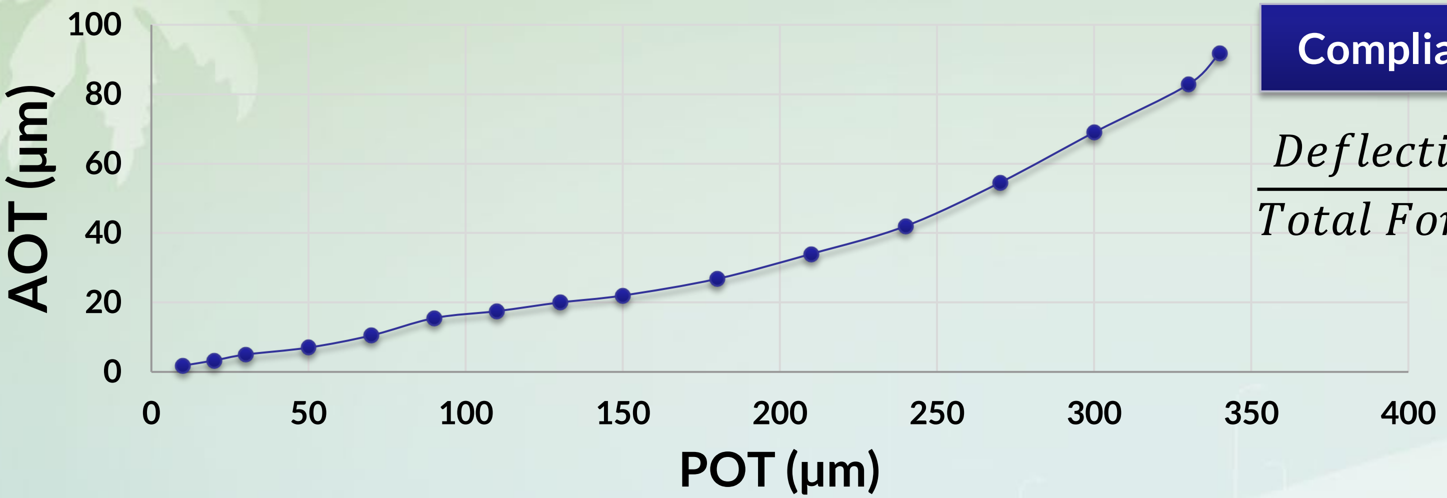
Deflection Study: Measurement Method

AOT/POT measurement method



POT (Programmed Over Travel) **= AOT** (Actual Over Travel) **+ bridge beam + headplate deflection + chuck deflection + other?**

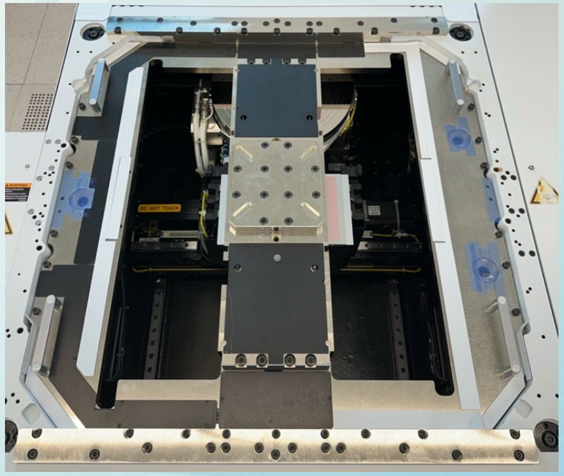
Entire System Compliance: AOT/POT



Compliance (TOT) = 1.5 um/kgf

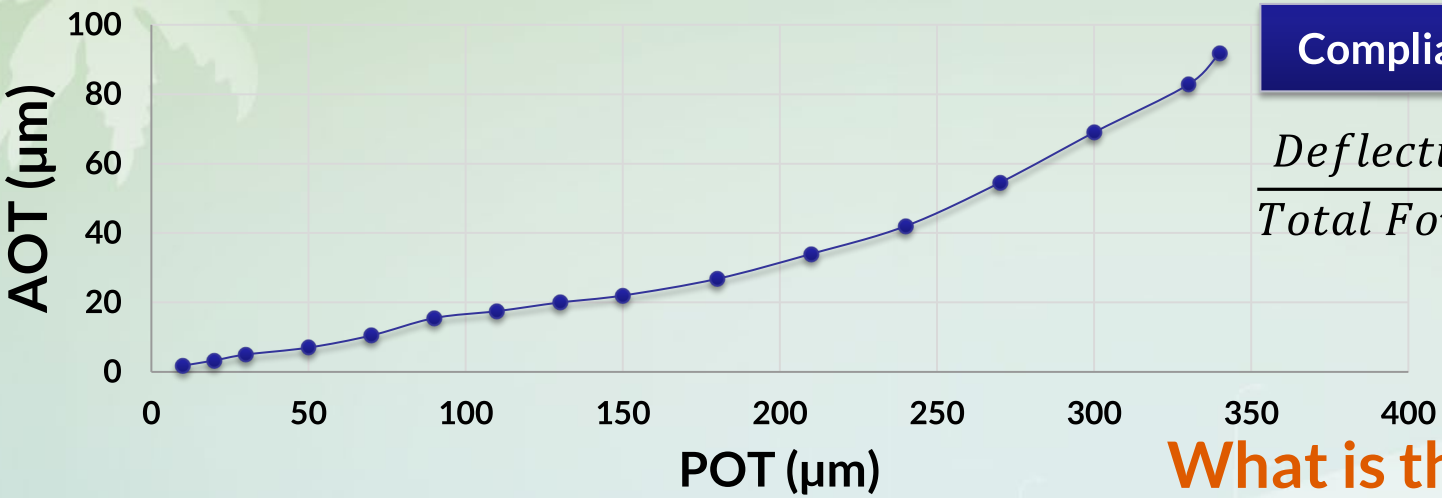
$$\frac{Deflection}{Total\ Force} = \frac{POT\ - AOT}{Total\ Force} = \frac{250\mu m}{167\ Kgf}$$

Setup Configuration	
Probe Card	PC_X6 with 95k pins and load force 167Kgf
Bridge Beam Model	Digital V93K DD
Prober Model	«A»
Prober Headplate material	Stainless Steel
Prober Inner Ring Material	Stainless Steel
Prober Chuck	Max- Load=300Kgf
Wafer	Al Blank 800µm thickness



Prober «A» configuration in Technoprobe

Entire System Compliance: AOT/POT



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What is the root cause of this Deflection?

Setup Configuration	
Probe Card	PC_X6 with 95k pins and load force 167Kgf
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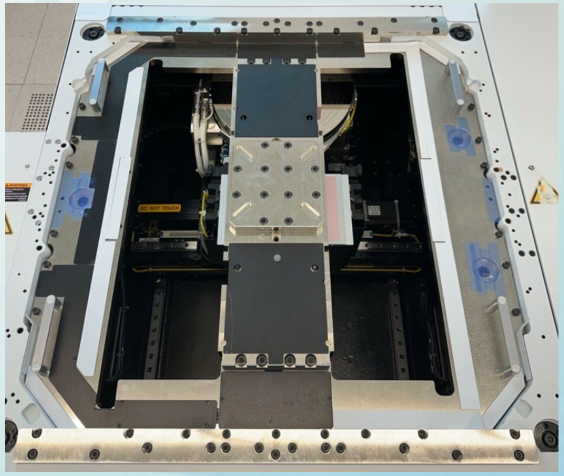
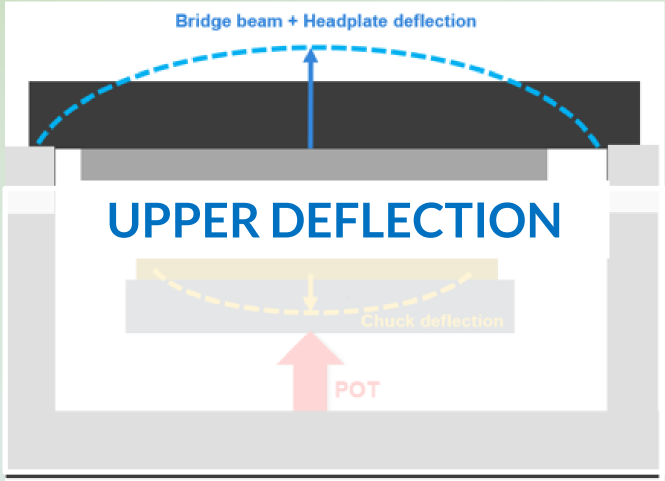
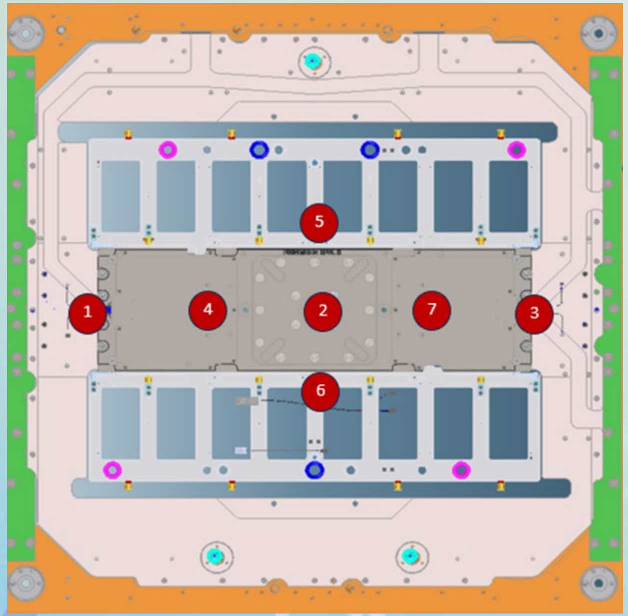


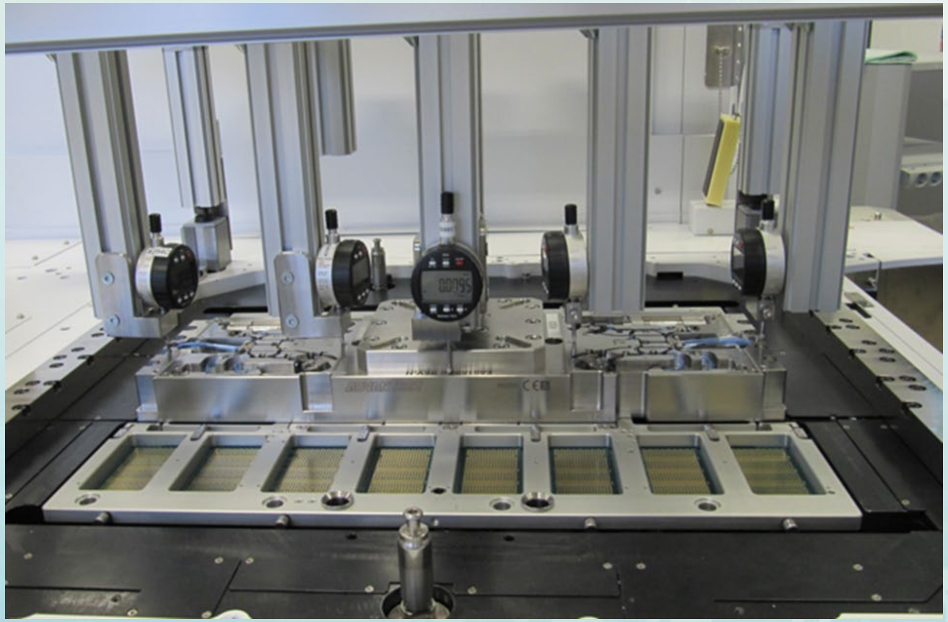
Prober «A» configuration in Technoprobe

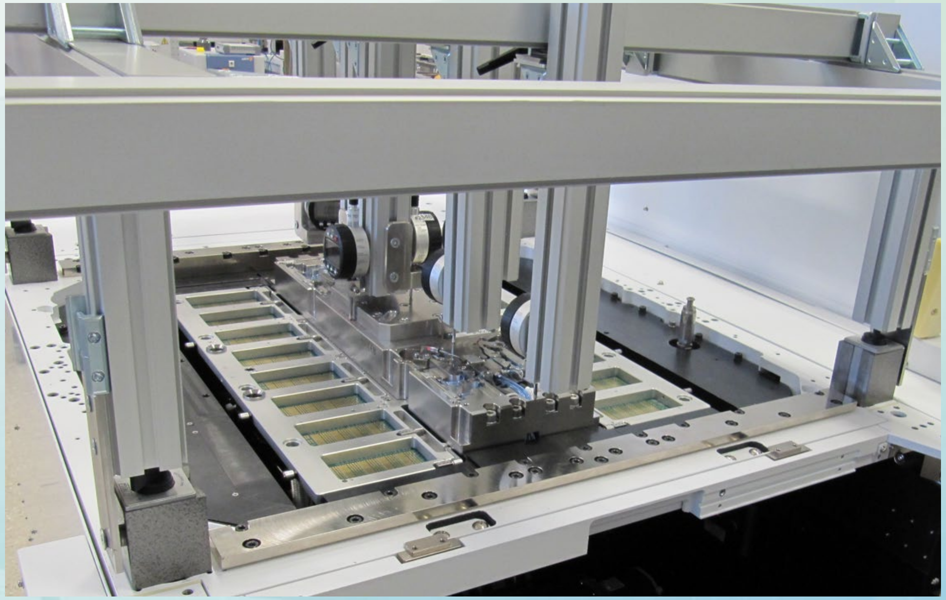
Measure of Deflection Components



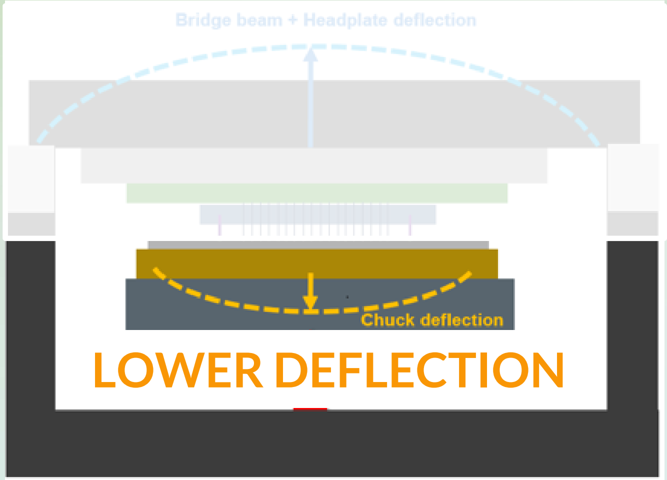
Bridge Beam, Prober headplate and inner ring vertical displacements are measured with Dial Gauges



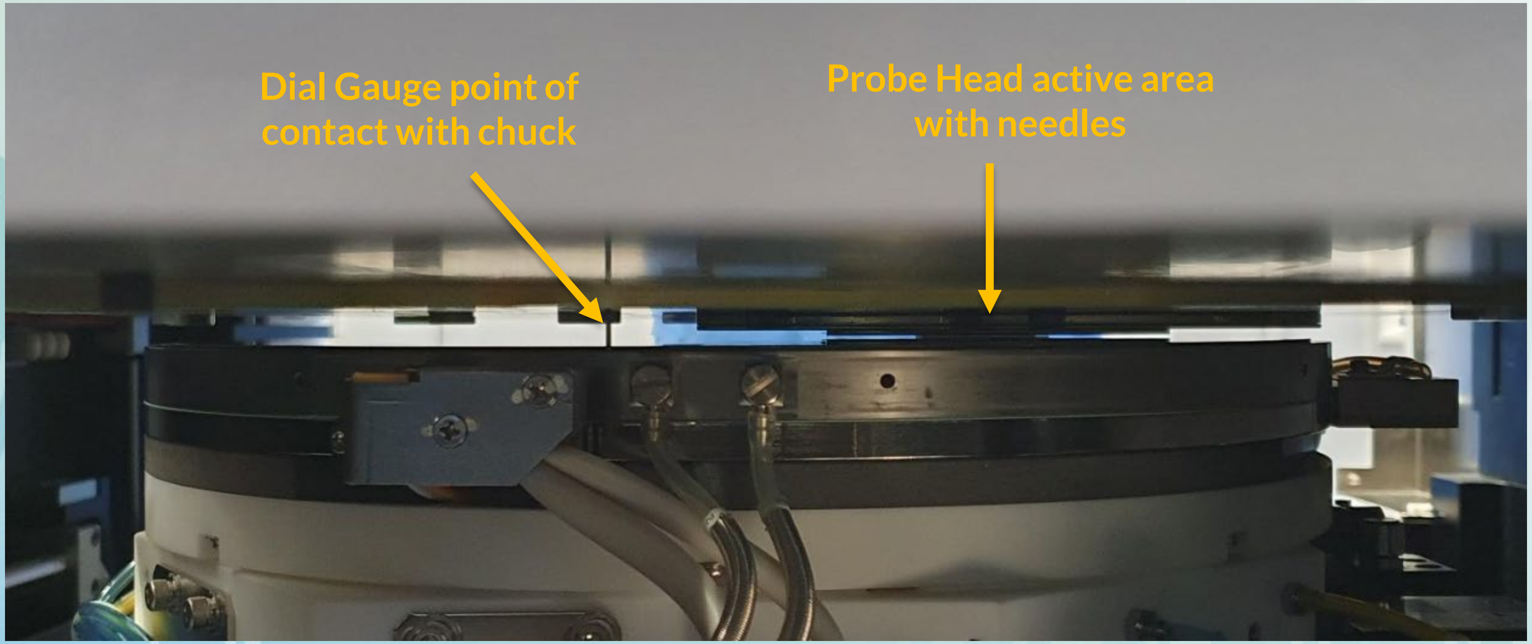


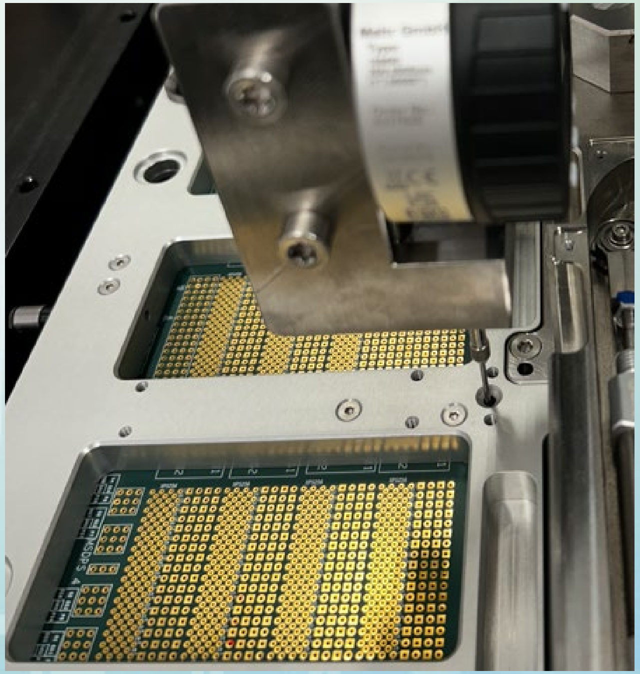


Measure of Deflection Components

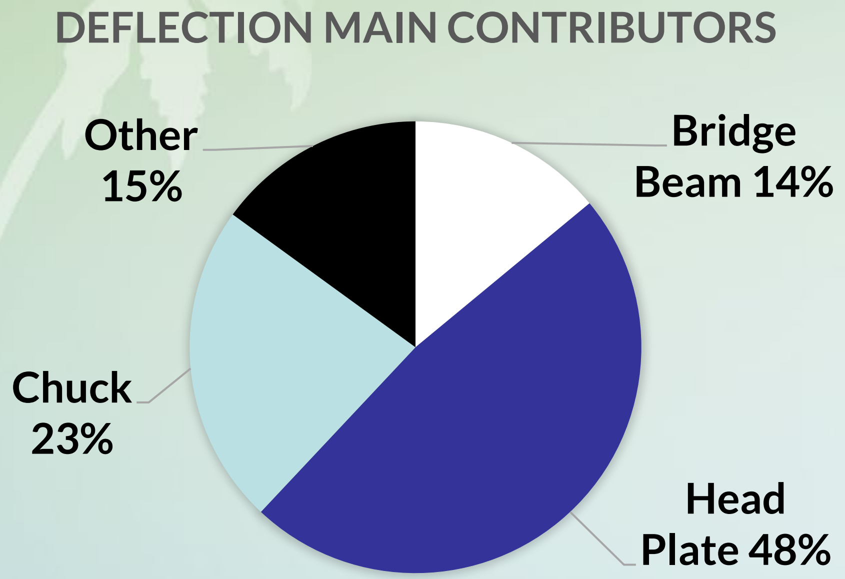


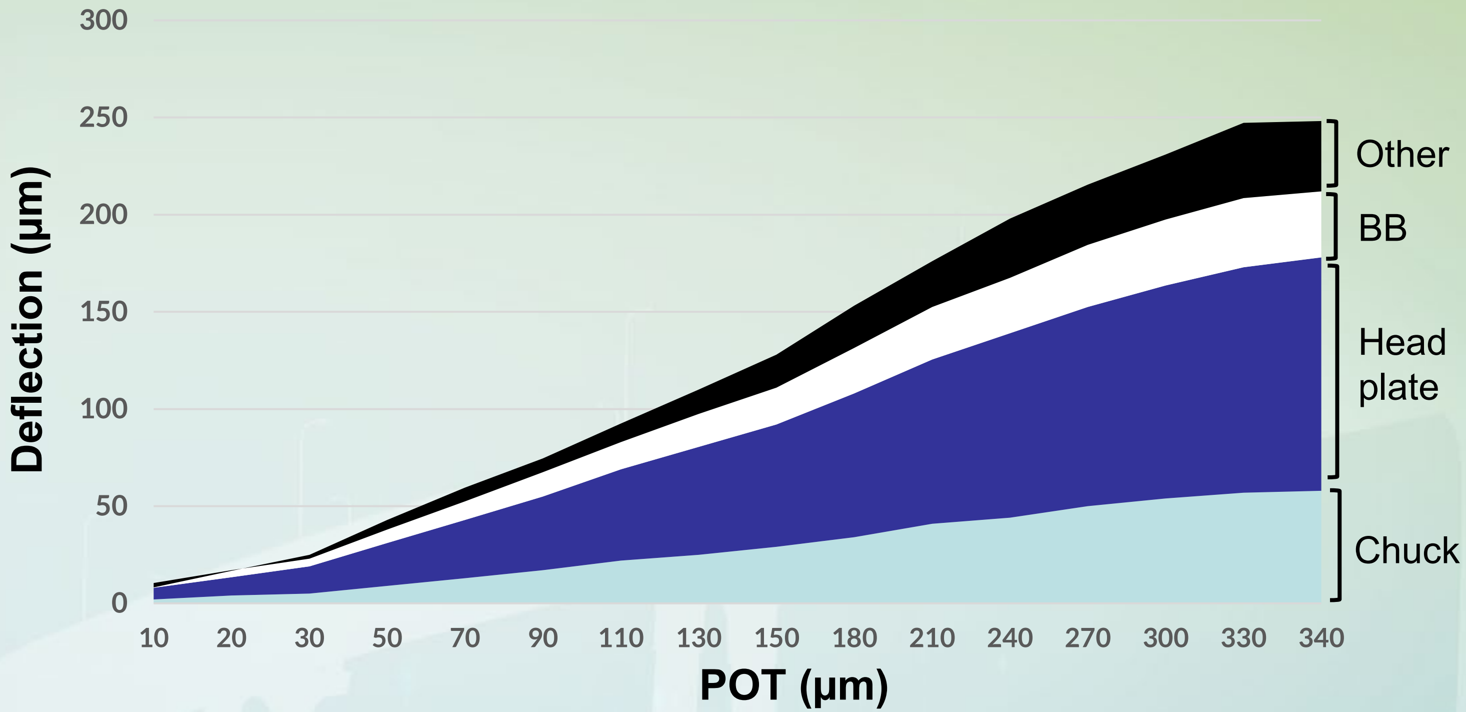
Chuck vertical displacements is measured with Dial Gauge inserted in hole through PCB





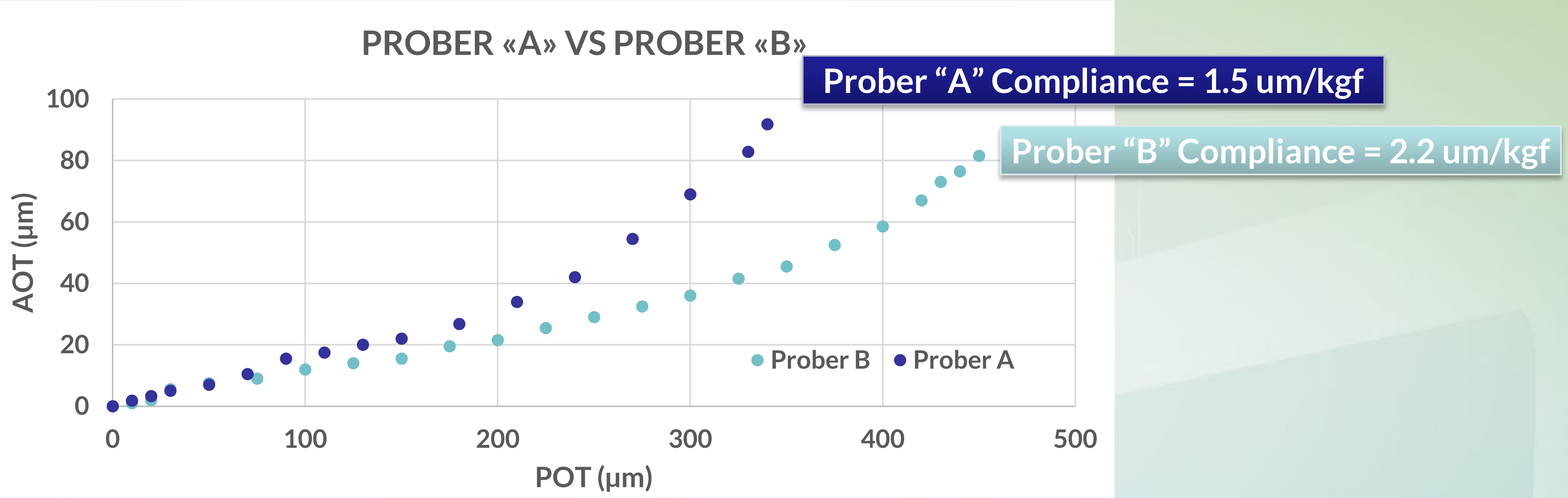
Measure of Deflection Components



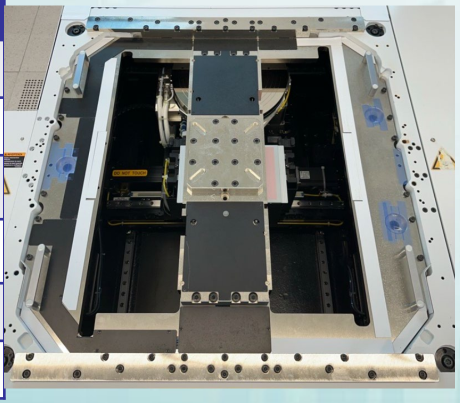


Component	Deflection	Compliance	Percentage %
Prober Head Plate + Prober Inner ring	120 μm	0.72 μm/Kgf	48%
Bridge Beam (center - edge)	34 μm	0.2 μm/Kgf	14%
Chuck	58 μm	0.34 μm/Kgf	23%
Other	38 μm	0.23 μm/Kgf	15%
Total	250 μm	1.5 μm/Kgf	100%

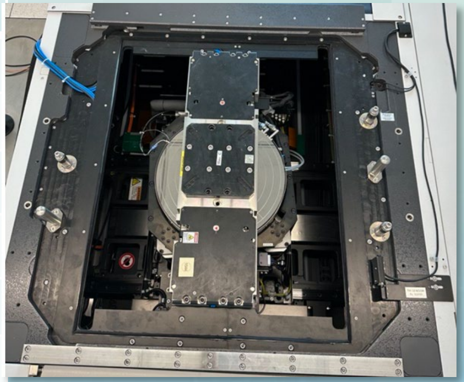
Impact of Prober Configurations



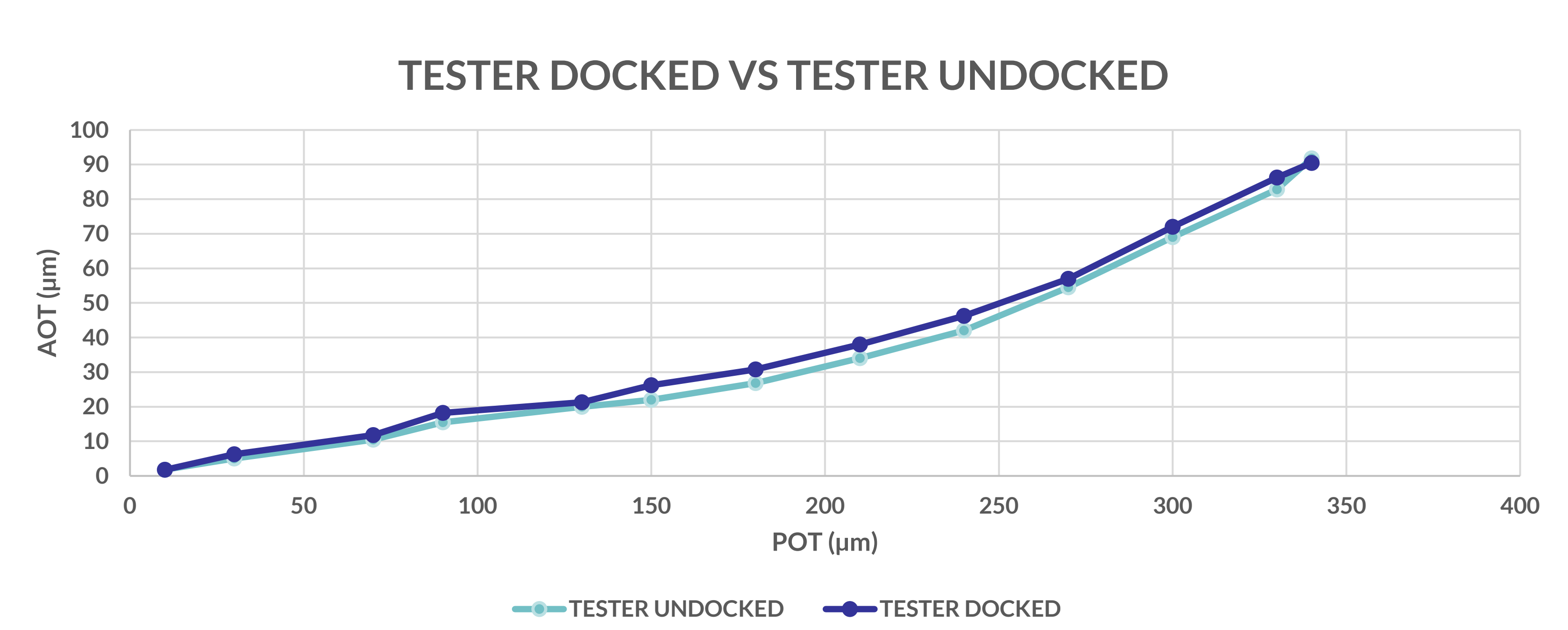
PROBER A	
Probe Card Force	167Kgf
Bridge Beam Model	Digital V93K DD
Prober Headplate	Stainless Steel
Prober Inner Ring	Stainless Steel
Prober Chuck	Max Load=300Kgf
Wafer	Al Blank 800µm thickness



PROBER B	
Probe Card Force	167Kg
Bridge Beam Model	Digital V93K DD
Prober Headplate	Aluminum
Prober Inner Ring	Aluminum
Prober Chuck	Max Load=300Kgf
Wafer	Al Blank 800µm thickness



Impact of V93000 SX Tester Docking

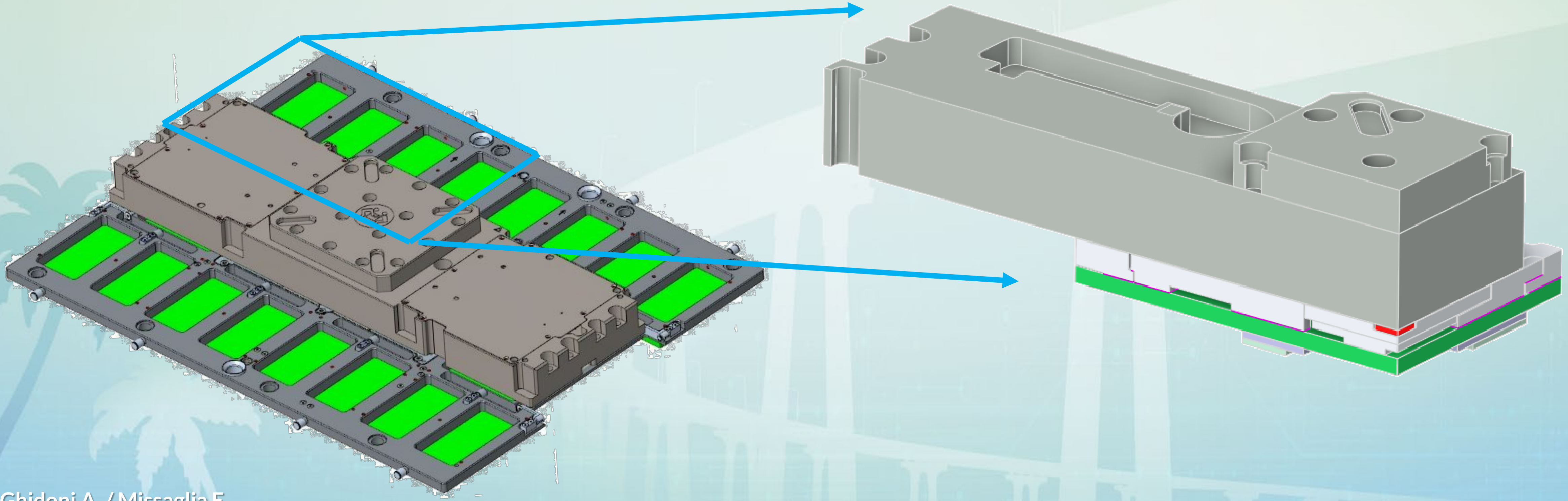


Finite Element Simulation

- FE Geometry
- Quarter Symmetry Model
- Boundary Conditions
- Compliance
- Simulation vs Exp. Test comparison

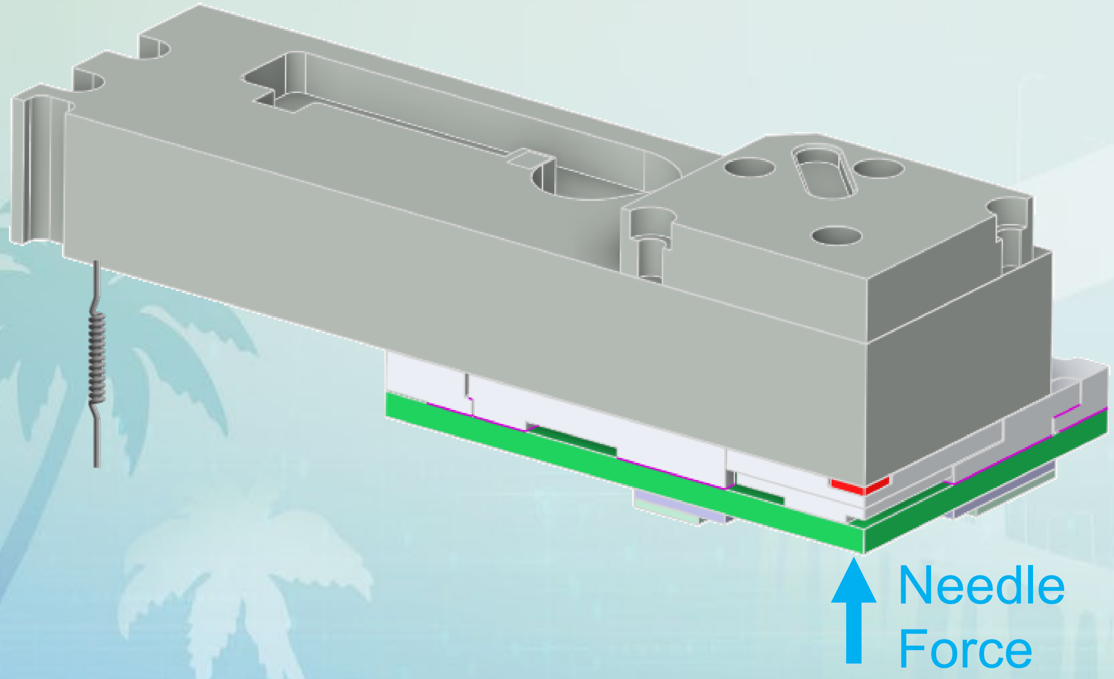
Finite Element Simulation

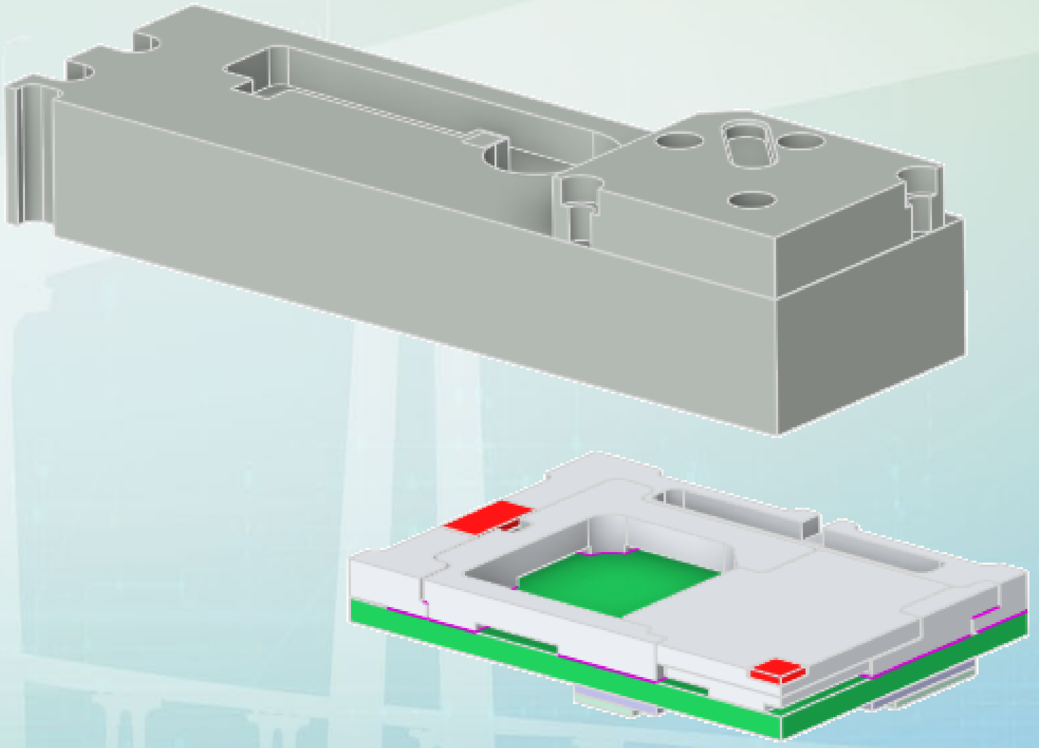
- Quarter Symmetry model
- Bridge Beam + Probe Card Simulated (Central Portion)



Finite Element Simulation

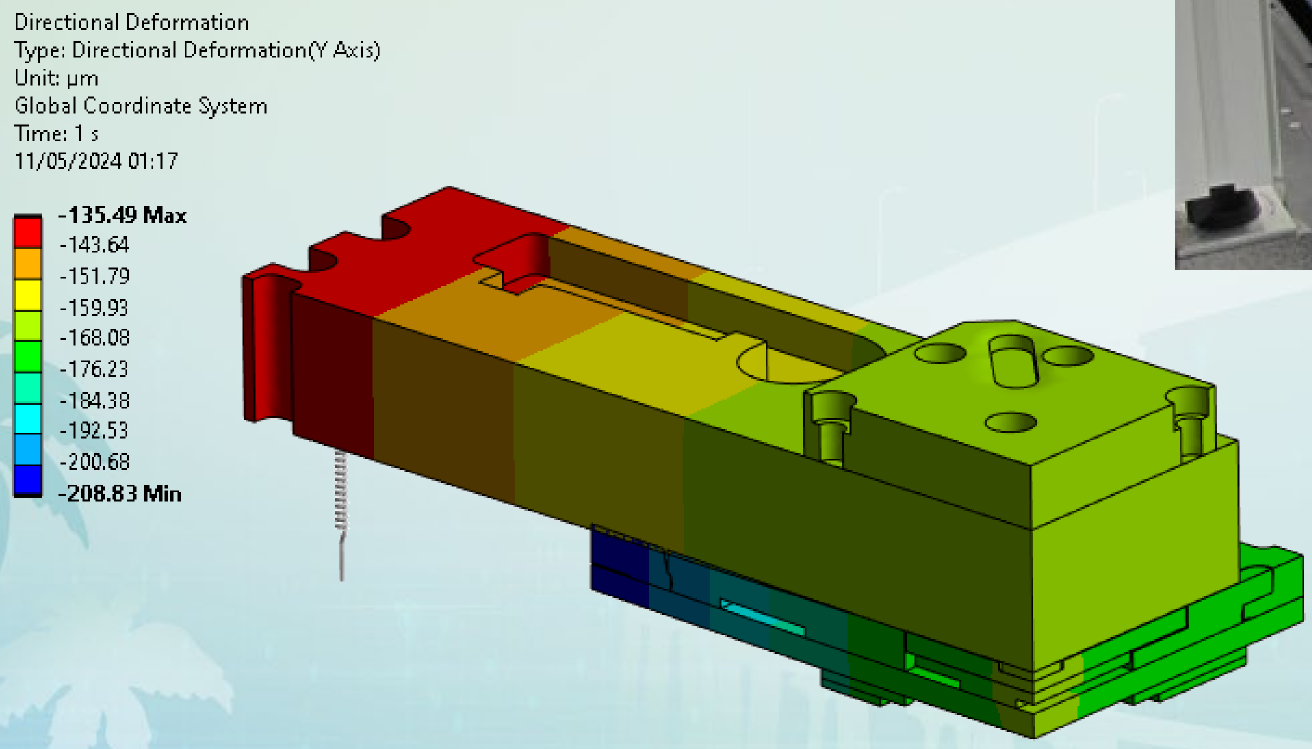
- In the actual prober setup, the Bridge Beam is fixed to the inner plate, which is modelled with an equivalent stiffness elastic spring.
- The docking is simulated with contacts between the stiffener and Bridge Beam
- Vertical needle force is applied on wafer side of the Probe Card

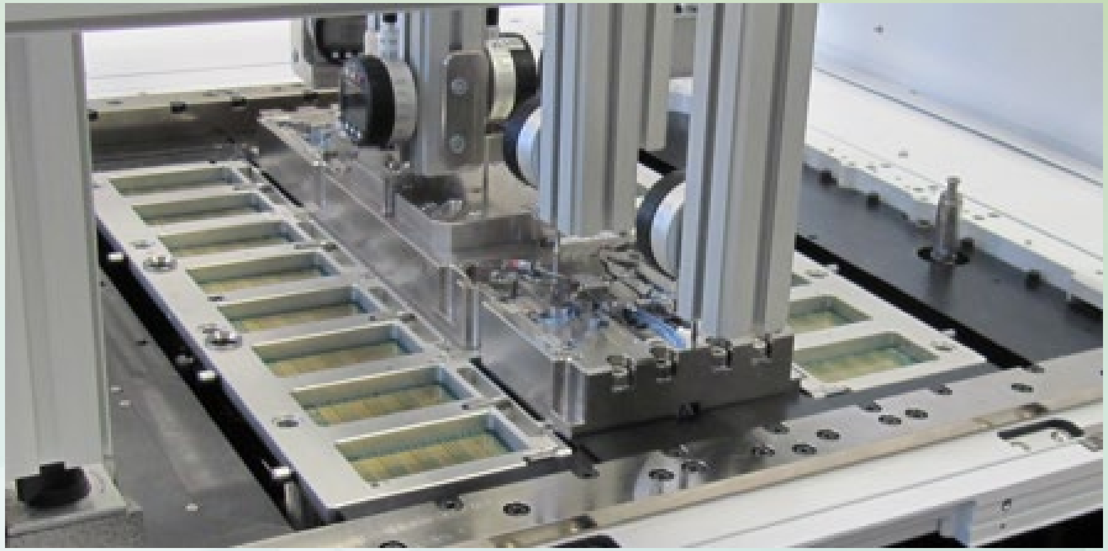




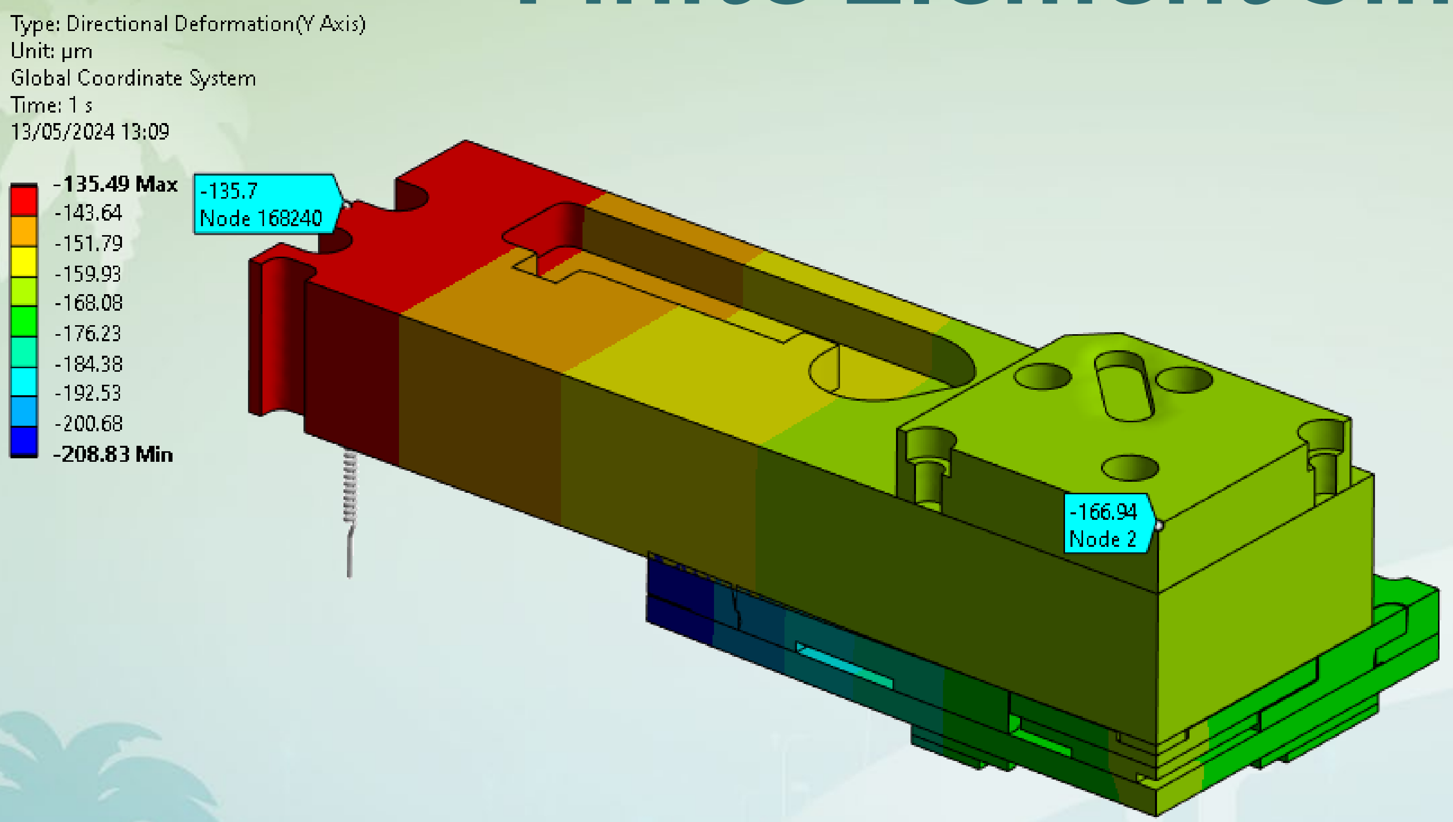
Finite Element Simulation

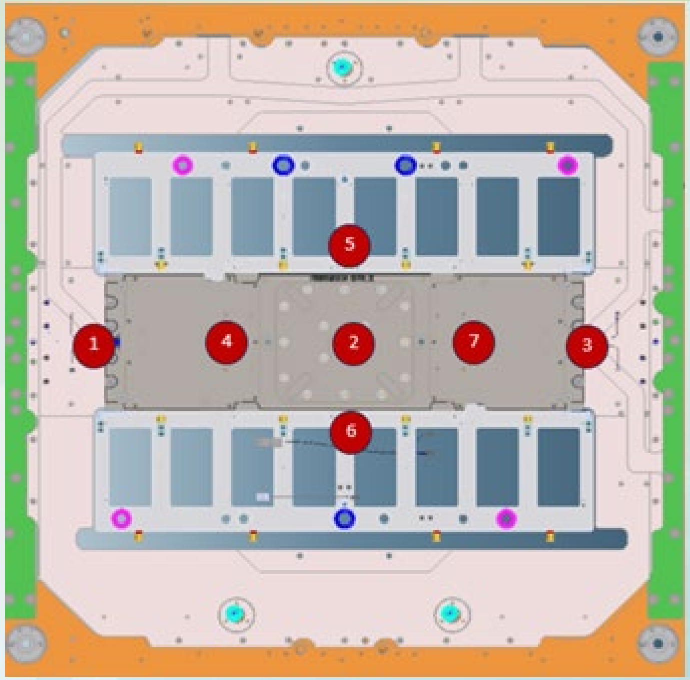
- 5% Error in Simulated Vertical Displacements
- Simulated Compliance = 0.98 um/Kgf (w/o Chuck Deflection)





Finite Element Simulation





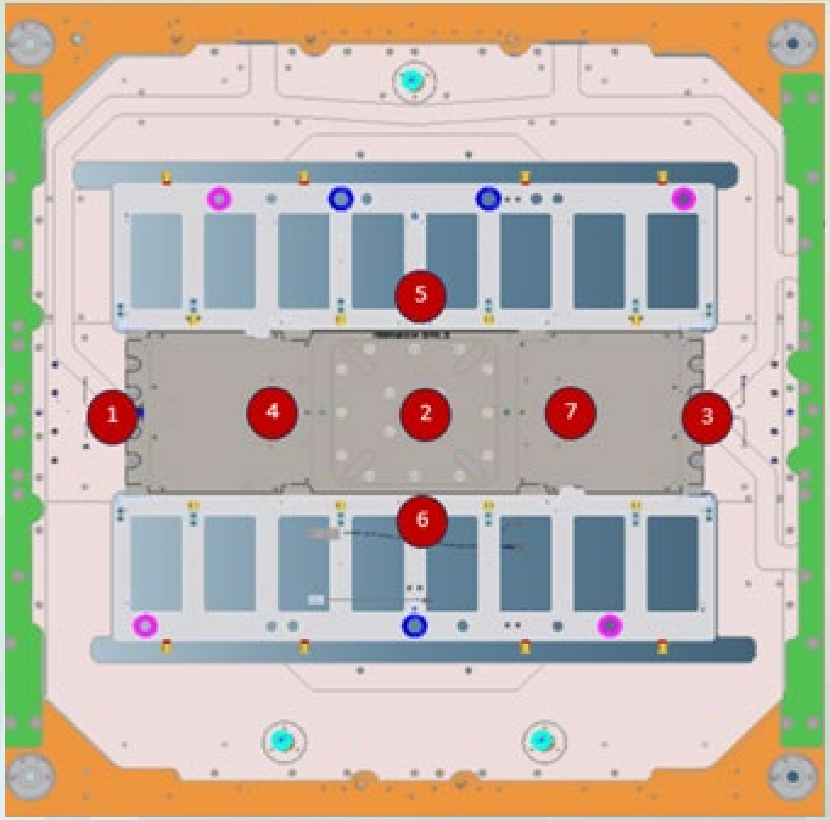
Vertical Displacement	Experimental Results	FE Simulation	%Error
Center Stiffener (pt.2)	169 µm	167 µm	1% ✓
Outer Stiffener (pt.3)	130 µm	136 µm	< 5% ✓

The simulated vertical displacements are matching the experimental values up to 5% error

Finite Element Simulation

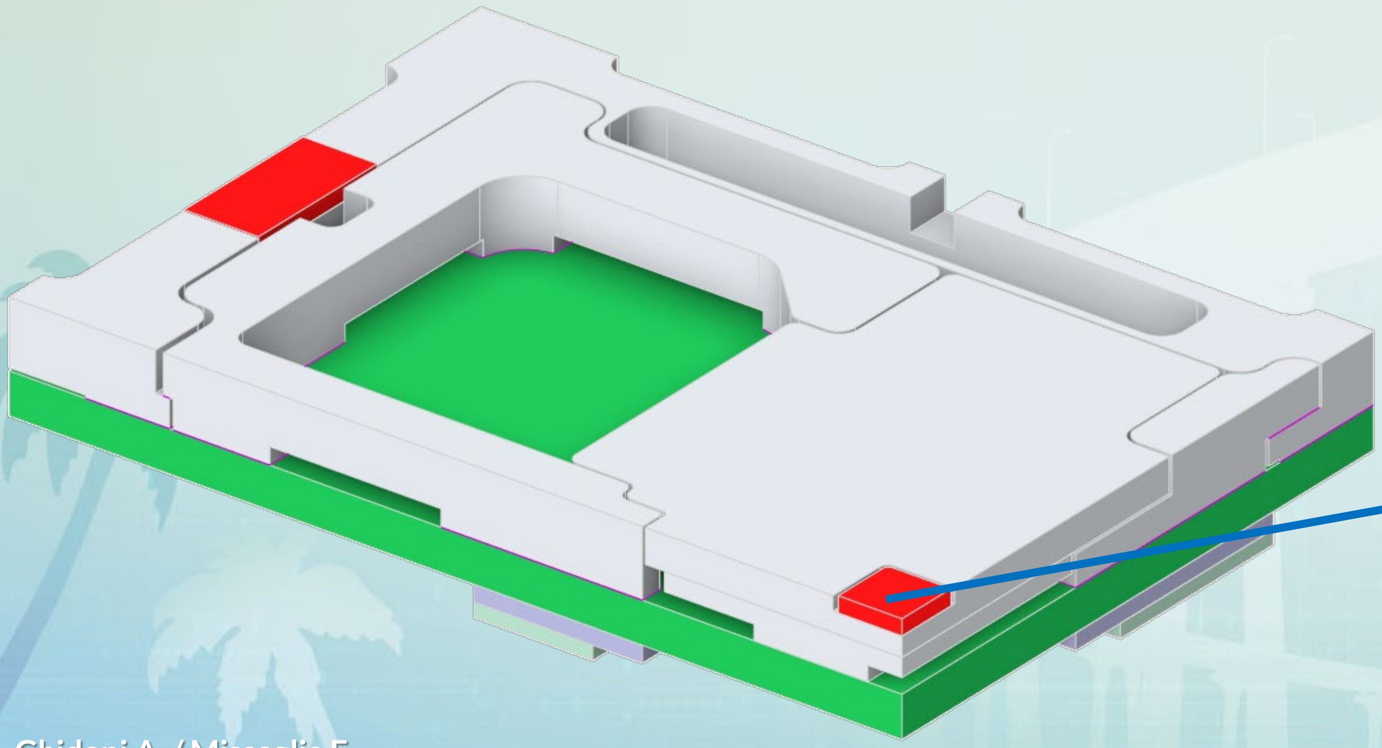
- The central portion of the Bridge Beam remains flat under load
- The estimated flatness (FEM) of the Active Area under load is 2 µm.

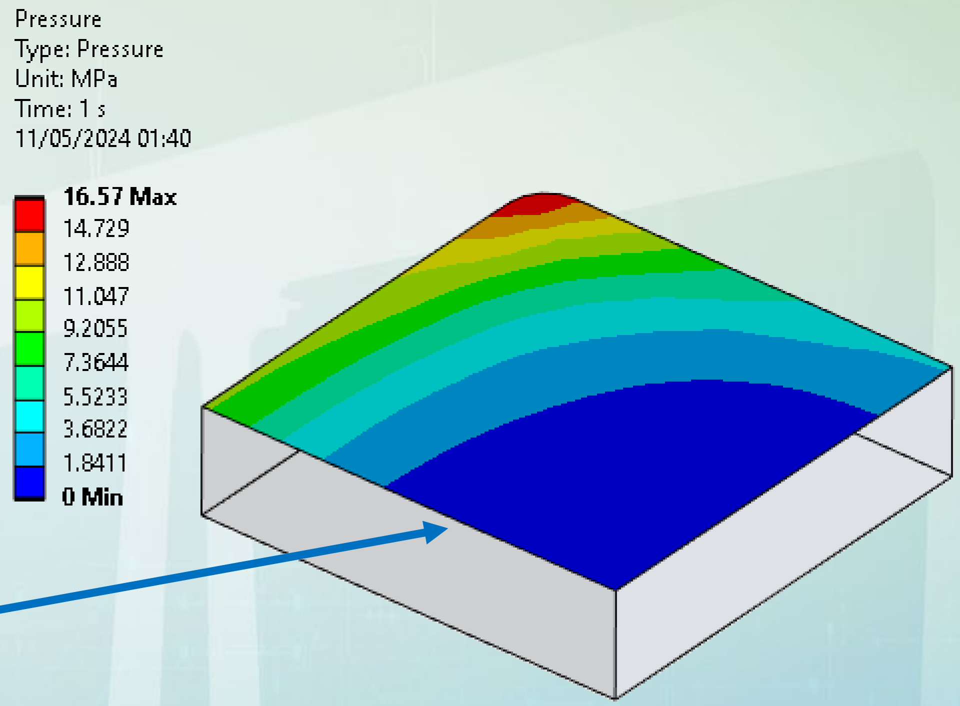
Vertical Displacement under Probe Head Load	Experimental Results	FE Simulation	Bridge Beam Flatness
Point 5	168 **µm**	167 µm	9 µm
Point 2	169 **µm**	167 µm	
Point 6	168 **µm**	167 µm	
Point 4	160 µm	158 µm	
Point 7	163 µm	158 µm	



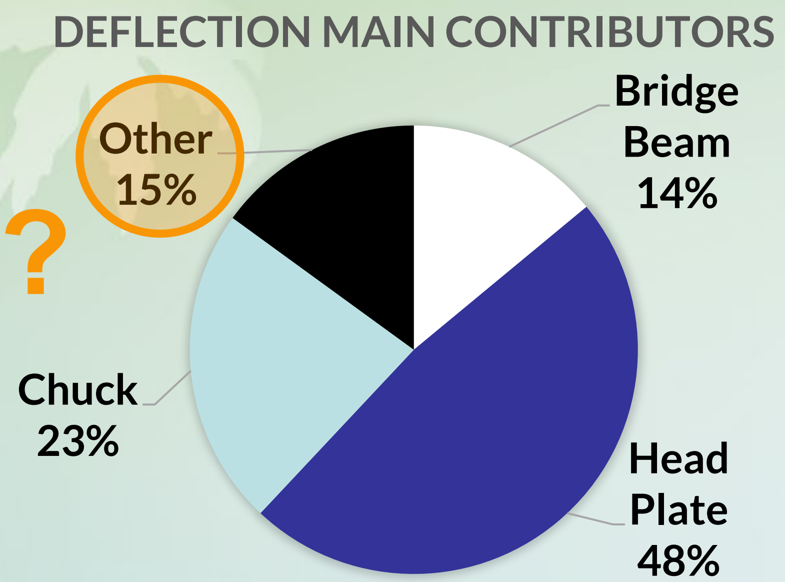
Finite Element Simulation

- During the Docking Phase a mechanical contact is established between the Probe Card stiffener and Beam Bridge.
- The Pressure distribution on central portion of stiffener is calculated.



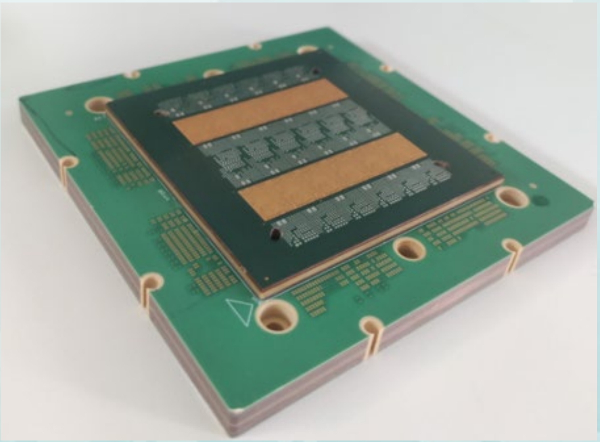


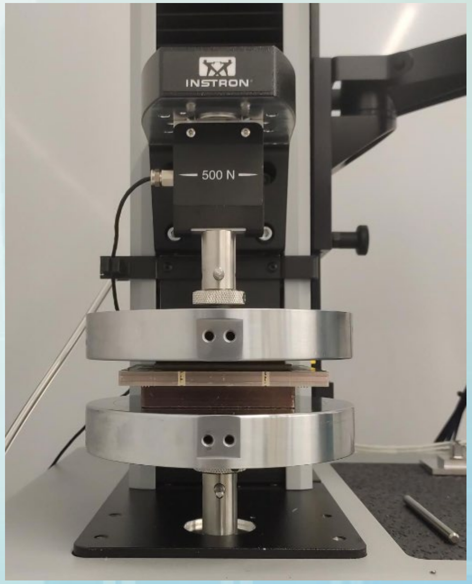
Deflection Main Contributors



The 'Other' Contributor is still under considerations and tests are ongoing:

- The Probe Card Compliance is investigated by means of experimental compression tests on dedicated specimens. Very low compliance values are found.
- Measurement reference not on ground -> but on corners of prober body structure
- Each of the experimental data are affected by measuring errors, especially on chuck measurements. The uncertainty due to measure errors is very limited.





What about Probe Card Analyzer capability?

- Probe Card must be in house tested before delivery to customer
- Probe Card testing must be reliable to avoid any early electrical issue on field.
- As well as test cells, probe card analyzer (PCA) must enable high load PCs testing
- Current PCA (PRVX4) max load capability is 150Kgf

➡ **Technoprobe has developed new PCA analyzer with enhanced chuck force limit (up to 350Kgf)**

FTPA (Probe Card Analyzer - PCA)

FTPA installed in TPI clean room

- **FTPA (internally-developed PCA)**
  - **Alignment**
  - **Planarity (optical, mechanical, electrical)**
  - **Electrical continuity**
  - **Leakage**
  - **C-Res**

Main Features: PRVX4 vs FTPA

	PRVX4	FTPA
Max Probe-head Size	112.5 mm x 112.5 mm	320mm
Max Chuck Force	80kg for EX, 150kg for STD	350kg
Max Travel	23mm for EX, 8mm for STD	110mm
Overall Accuracy	7 um	<2um
Test Time	More than 16h for a 50K pins PH	We expect less than 8h
Optical	1x2D with limited field of view	1x2D with large field of view 2x3D (interferometers)
Electrical Channels	Up to 6000	Up to 18.432
Autoloader	No	Yes up to 5 PCs
Flying probes	1	2 independent
Tilt Correction	No	Yes
Repair	Yes on the equipment (flipping)	TBD

Main Future Applications/Challenges

	PRVX4	FTPA
IoTs, Small devices, Std ICs	YES	YES but like using a Ferrari for cities
uControllers 300mm	NO	YES
CPUs	Partially	YES
GPUs, AIs	Partially (below 70k probes)	YES
CIS 300mm	NO	YES
Memories	NO	YES
Device Loopbacks	With another counter-MLO	YES (Native)
Small pads, TSVs	NO	YES
High Pin-Count Devices	Up to 6,000 channels	Up to 18,432 Channels
Small Tips/Probes	NO	YES
High Productivity	NO	YES
Repair	YES	YES
RF	NO	TBE

Conclusions

- Ultra High Pin Count Probe Card has been developed to maximize pin count while keeping total load force as low as possible:
  - UXS Probes lead to 20% total load reduction
  - Probe Head mechanical structure has been customized based on simulation results
- AOT/POT measurements have been used to quantify compliance of entire system:
  - Compliance (TOT) = 1.5 µm/kg
  - Deflection (TOT)= 250 µm (with 340µm of POT)
- Measurements of main deflection components have been performed:
  - Prober Head Plate + Prober Inner Ring = 48% ; Chuck = 23% ; Bridge Beam=14% ; Other=15%
- Different prober and tester configurations have been analyzed:
  - Material and design of the prober headplate is a key item for deflection reduction
  - No difference found in tester docked/undocked
  - Docking or undocking the tester has no impact to deflection
- FEM simulation shows good agreement with experimental data:
  - Center area of the Bridge Beam (Probe Head Area) remains flat even for high probe force
- New PCA was internally developed (FTPA) to increase chuck force limit (up to 350Kgf)

Follow-On work

95K pins (170Kgf)

→ Digital Bridge Beam

Complete Analysis:

- AOT/POT High Temperature
- AOT/POT stepping outside the wafer with some DUTs
- Investigation on other (15%) contributor to deflection

160K pins (280Kgf)

→ Digital Bridge Beam

Repeat deflection analysis to find system capability/limit

160K pins (280Kgf)

→ Extended Bridge for DUT Scale Duo Interface

Repeat deflection analysis to quantify DUT Scale Duo Interface benefit

Thank you!

Acknowledgement

The authors express their gratitude to Michael Ott, Markus Fahrner, Marc Mössinger from Advantest as well as Riccardo Acquaviva, Alberto Berizzi and Raffaele Vallauri from Technoprobe for their valuable contribution to this paper.

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