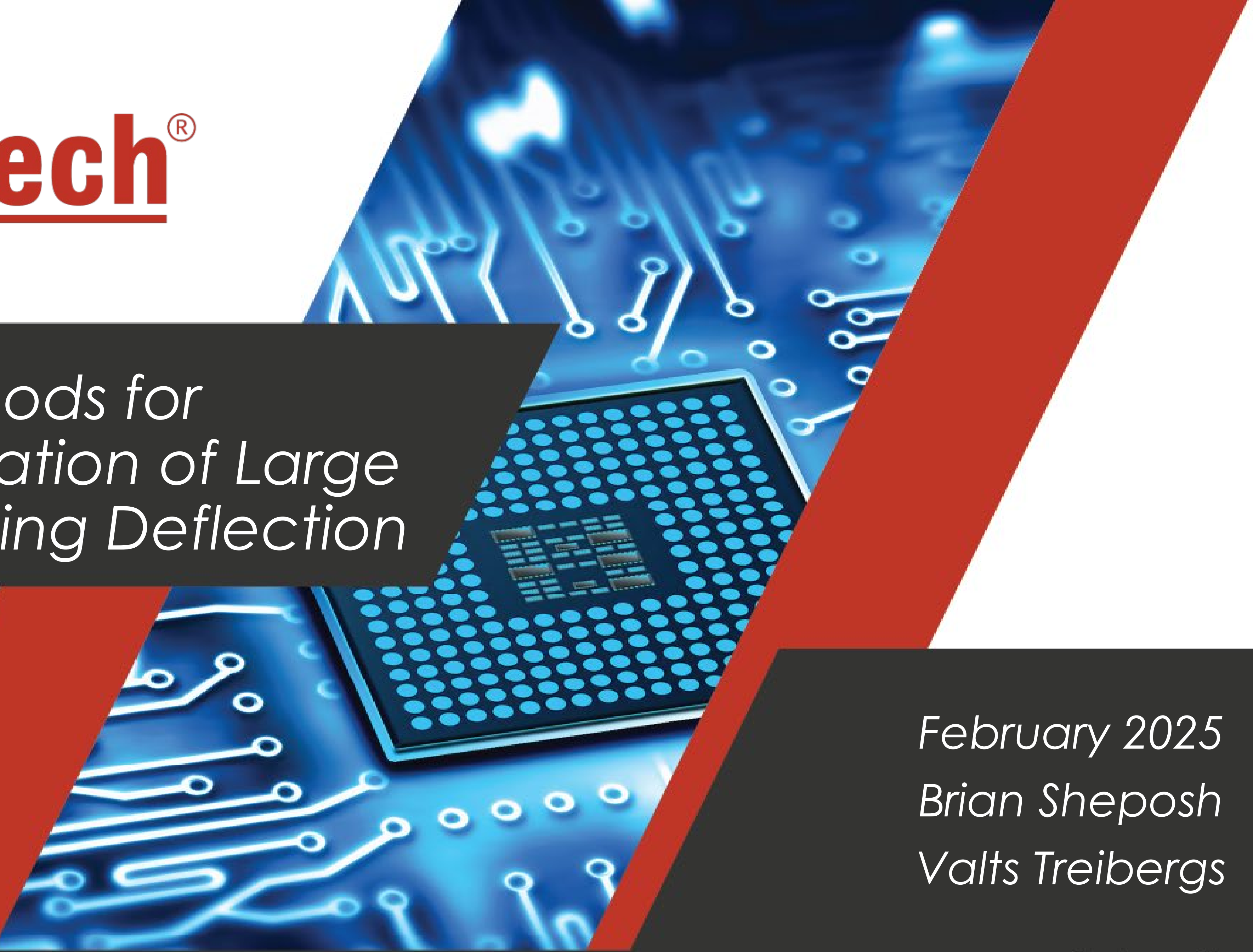
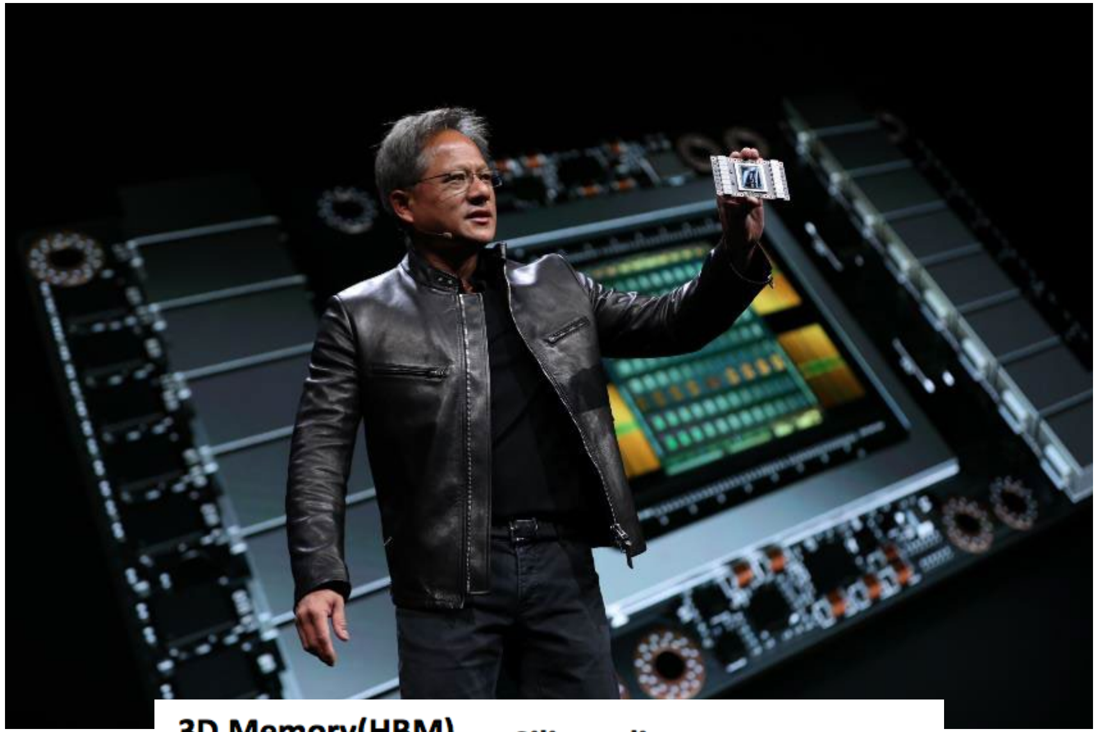
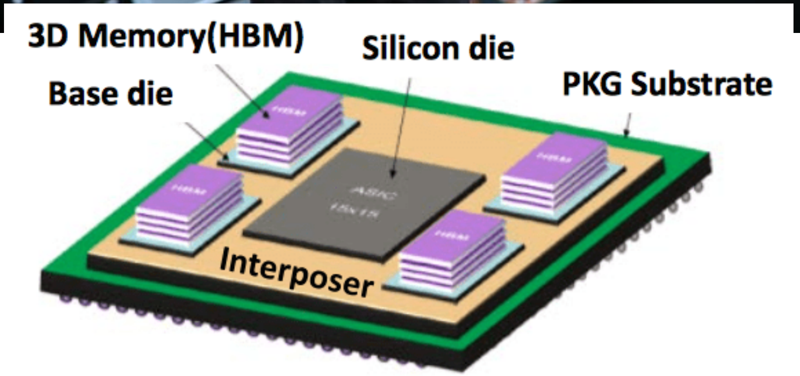
Methods for Characterization of Large Socket Housing Deflection



February 2025
Brian Sheposh
Valts Treibergs

AI Device Demands Larger Packages





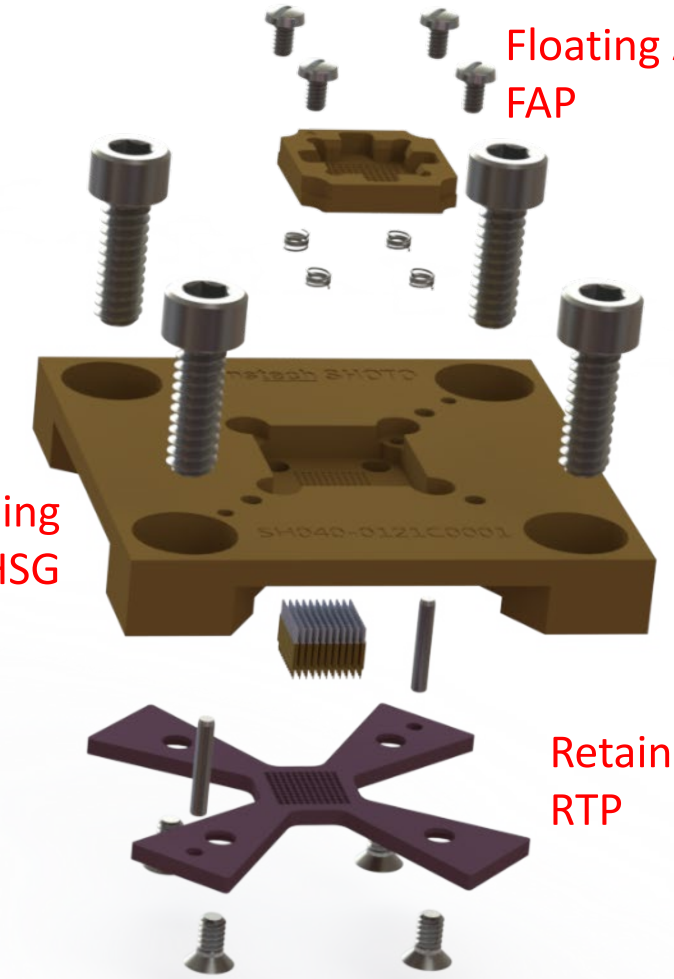
Many AI applications are moving to larger device packages with higher ball counts.

As spring probe housings become more densely populated, the need for housing strength must be considered to minimize housing bowing.

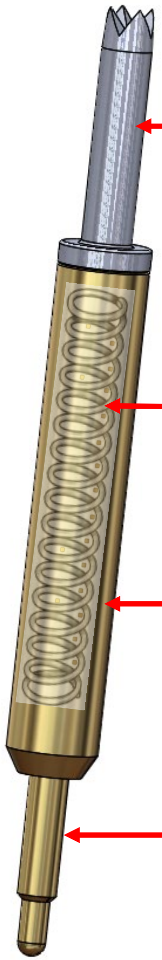
This presentation will provide validated methods for simulating housing deflection, the need for spring probe pre-load and its effect on deflection.

Benefits of the Johnstech® Spring Probe series will be discussed.

Spring Probe (YARI™ and SHOTO™) - Features



- Single-ended probe architecture for more consistent Cres performance
- Pd alloy tip
- Fully user serviceable contactor architecture – individually replaceable probes



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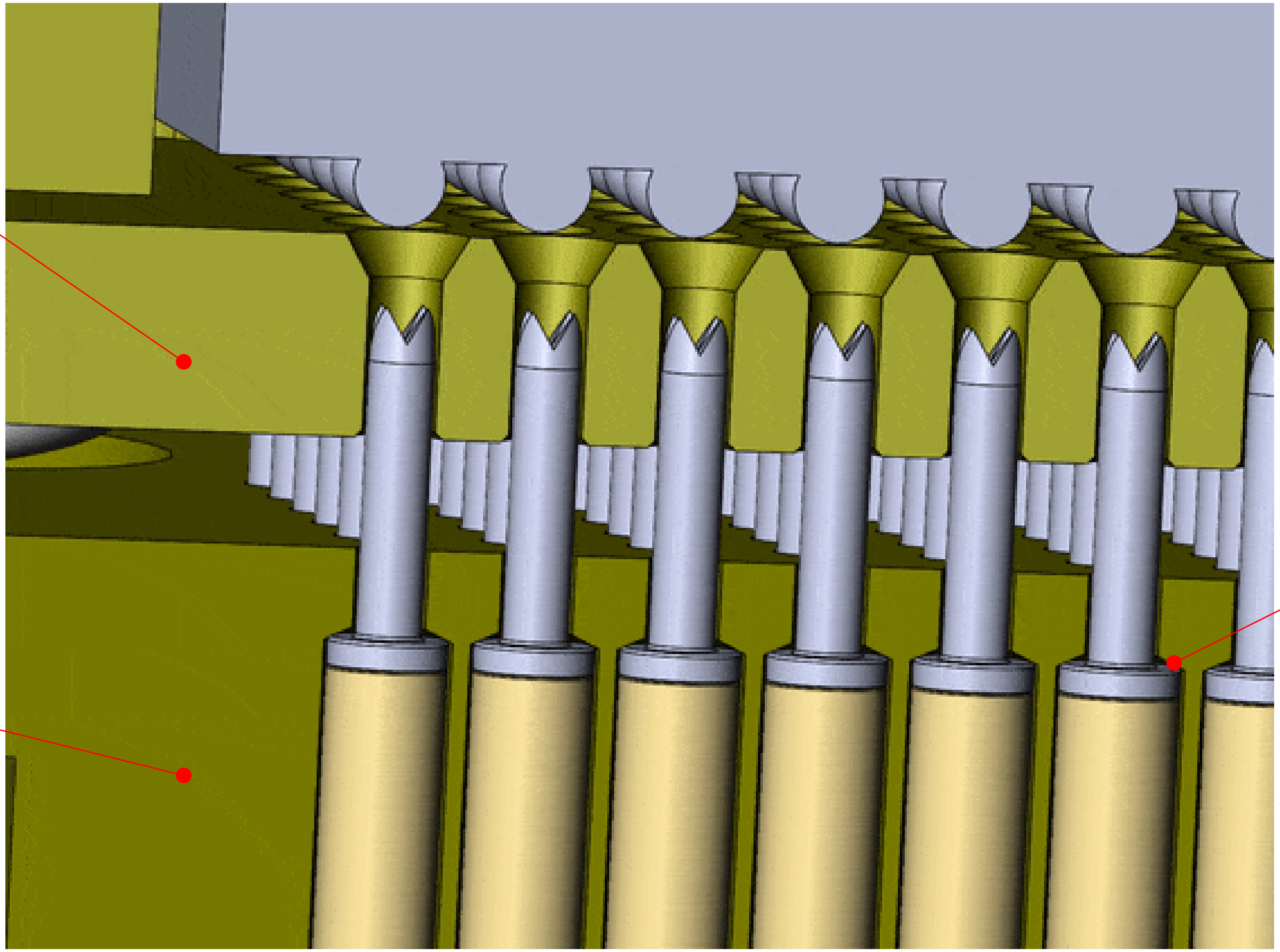
Probe Motion and Probe/Housing Interface

Floating
Alignment Plate
FAP

Housing
HSG



Preload Interface

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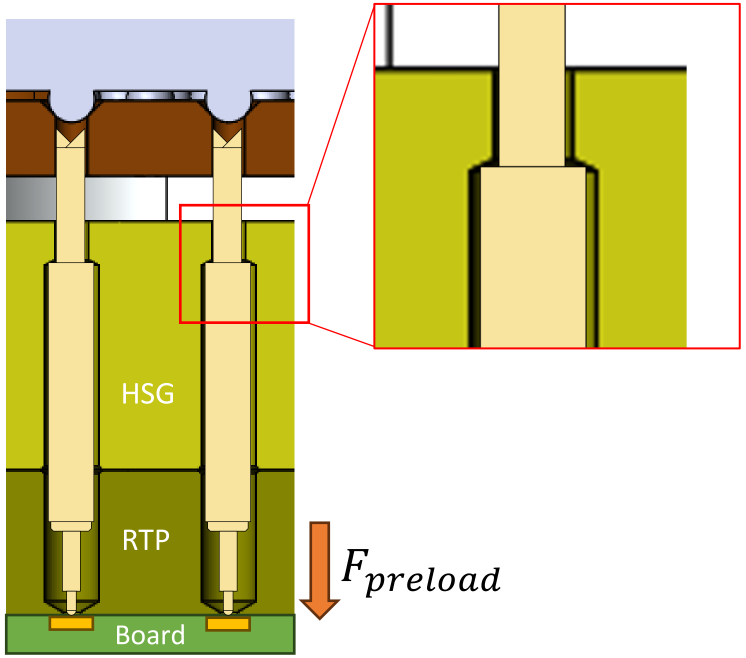
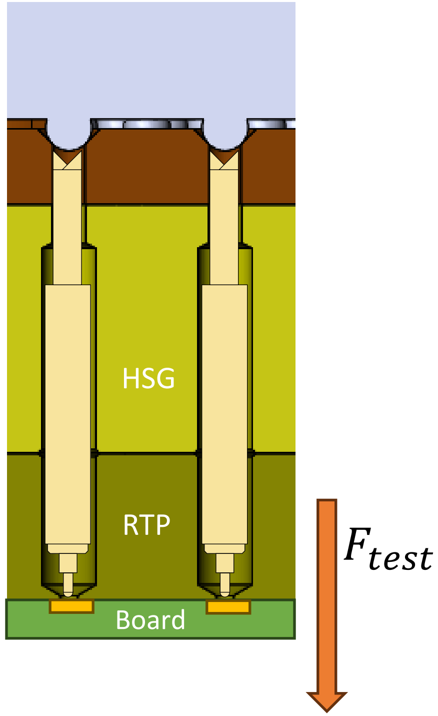
Properly Functioning Preload

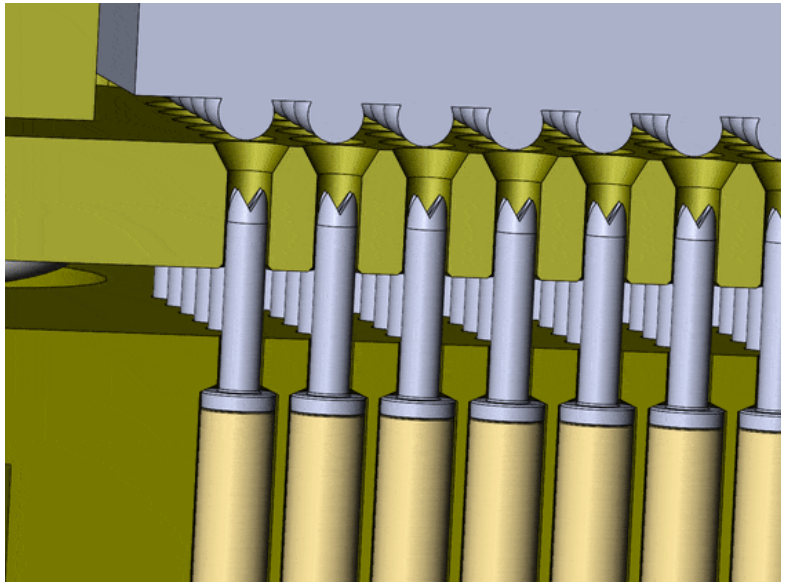


<u>Uncompressed state</u>
Consistent board contact is maintained to the board due to probe housing interface.

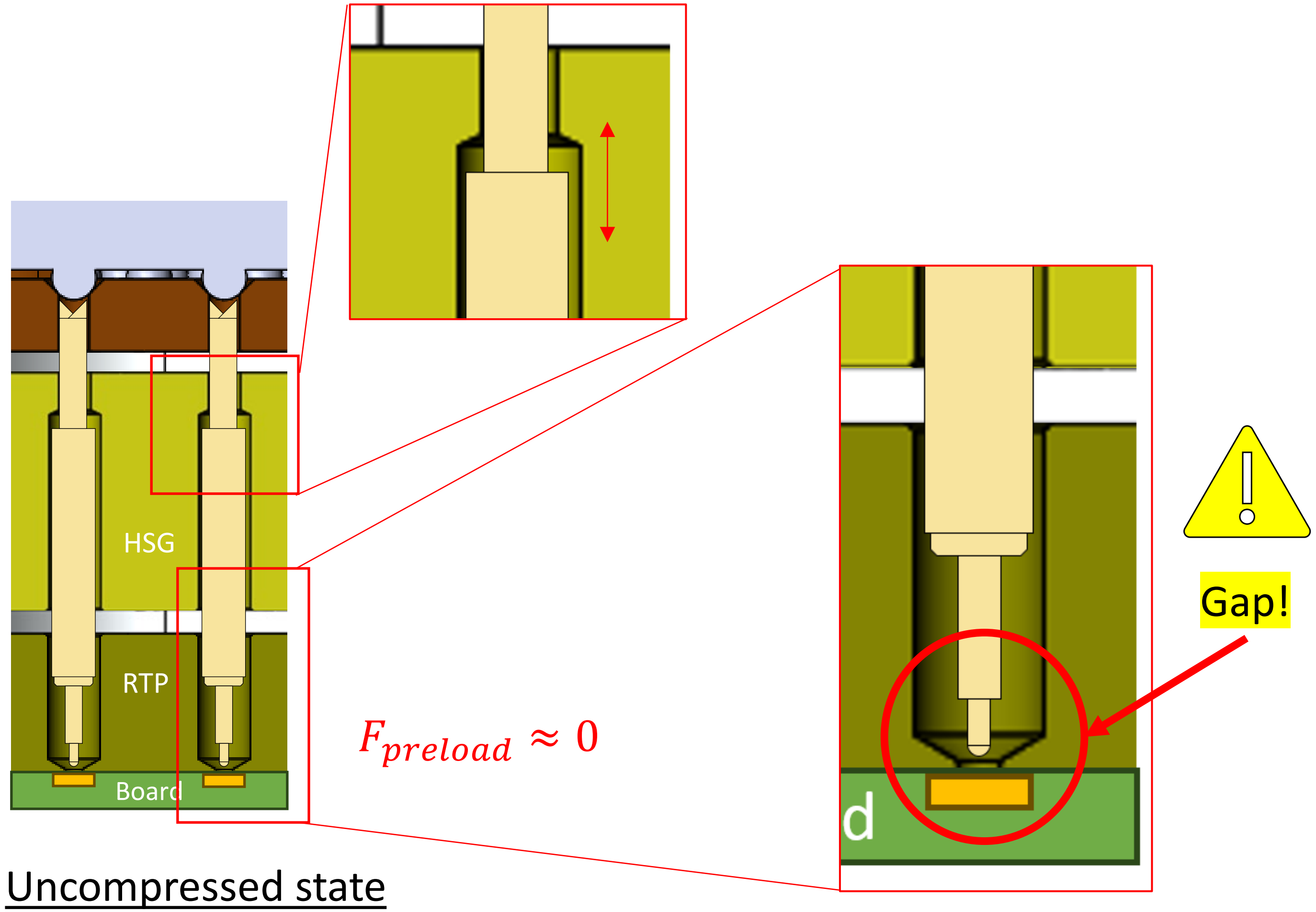


<u>Compressed state</u>
Board contact is maintained.

During the repeated motion between uncompressed and compressed, the probe will always remain in contact with the PCB pad.

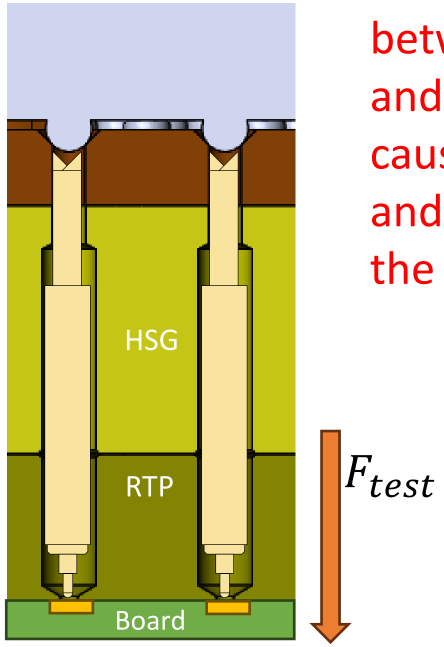


Loss of Preload Caused by Excessive Bowing



Uncompressed state

In situations where housing bow is present, the probe is not held against the loadboard and may lose contact with the PCB pad.



Compressed state

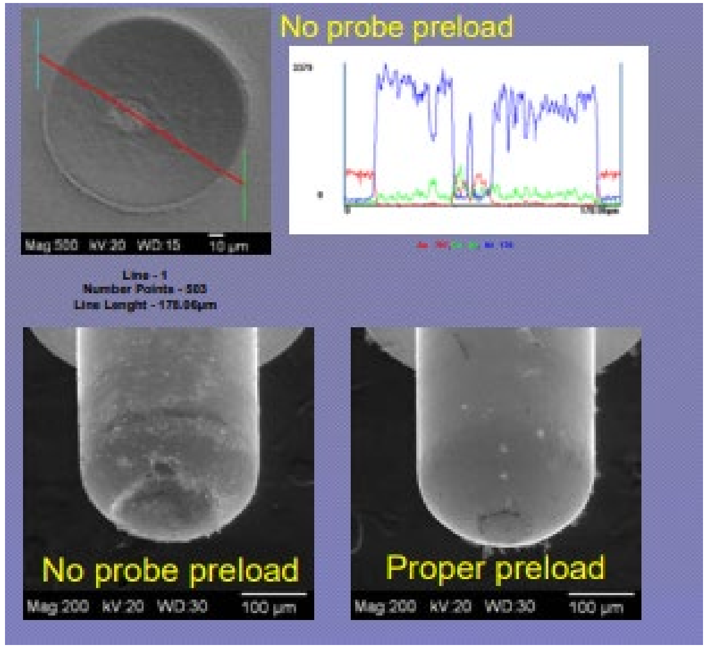
Board contact is maintained.

Board Chatter

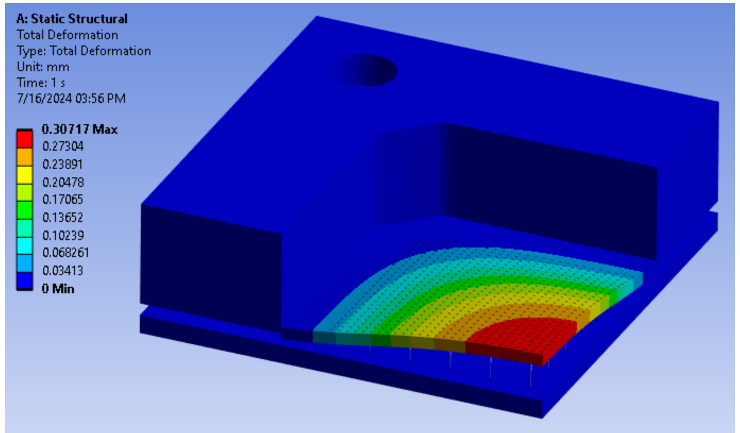
The repeated motion between uncompressed and compressed will cause the probe to make and break contact with the board.

Board Chatter Leads to Board Digging

- Probe chatter is a process where the PCB end of the probe makes and breaks contact with the PCB pad - “jackhammer”
- Board chatter can lead to early wear out of PCB pad.

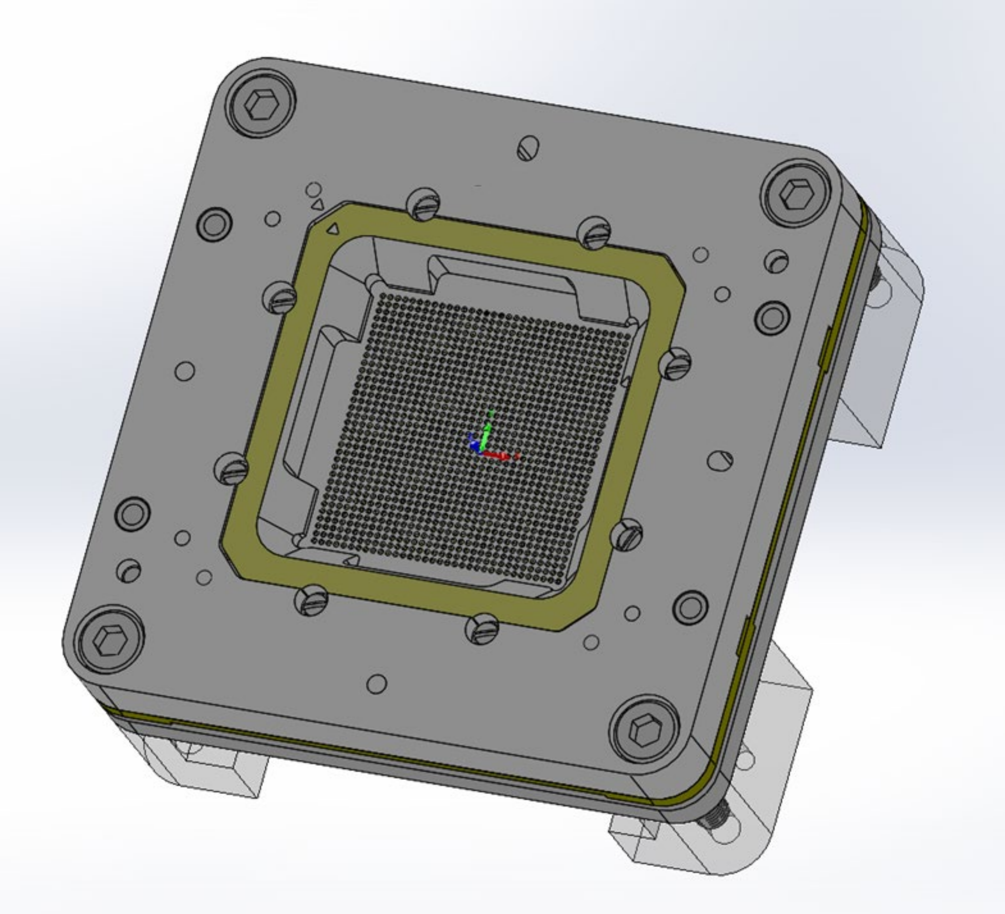


<u>Can be caused by</u>
too little preload
or
too much preload



Case Study with Shoto®

- 1156 Shoto® 050 Probes
- 23x23 package
- Simulation Steps
  1. Simplify model
  2. Define materials and constraints
  3. Determine probe preload and spring rate
  4. Simulation deflection
- Goals:
  - Determine if the designed preload of 6gm will be adequate.
  - Find the preload limit at which point probe chatter will occur.



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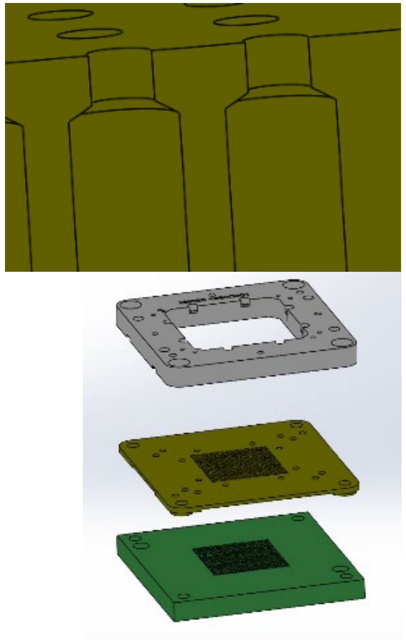
Simplify Model

Defeature

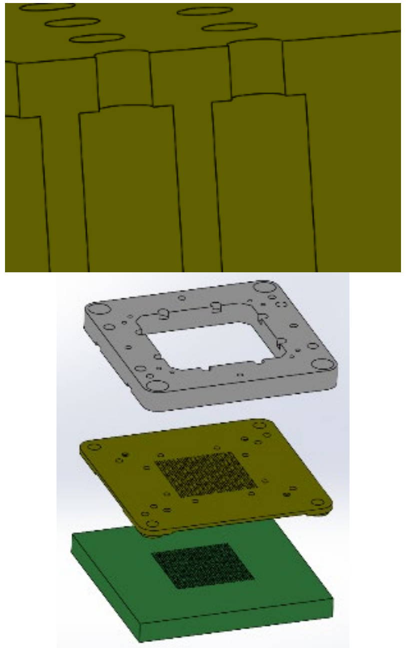
- Ignore partial array population
- Eliminate all non essential components
- Only need HSG, FRAME, PCB, Stiffener
- Probe C-drills –> flat bottom

Symmetry

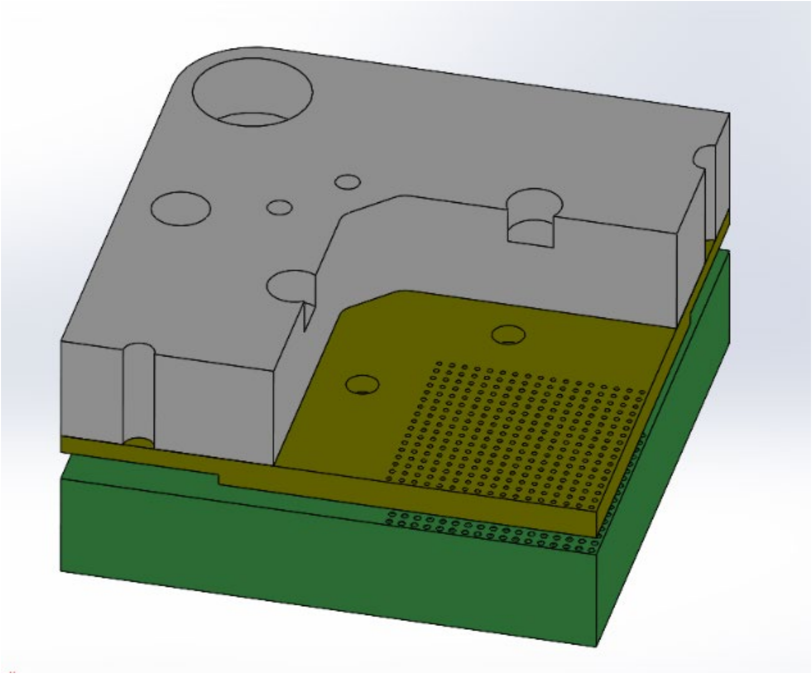
- Cut model to ¼ symmetry
- Consider even/odd arrays to ensure symmetric cuts



Defeature

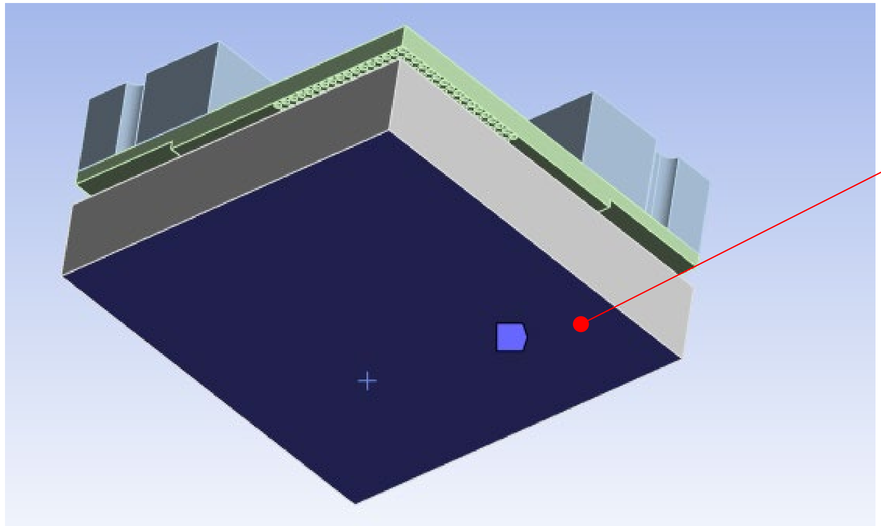


Symmetry



ANSYS Model setup

- PCB part
  - Stiffness Behavior: Rigid
  - Material: structural steel
  - Bottom fixed surface



Details of "bowing_337854-0001-1"

Graphics Properties	
Definition	
Suppressed	No
ID (Beta)	20
Stiffness Behavior	Rigid
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Structural Steel
Bounding Box	
Properties	
Statistics	

Details of "Fixed Support"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
ID (Beta)	53
Type	Fixed Support
Suppressed	No

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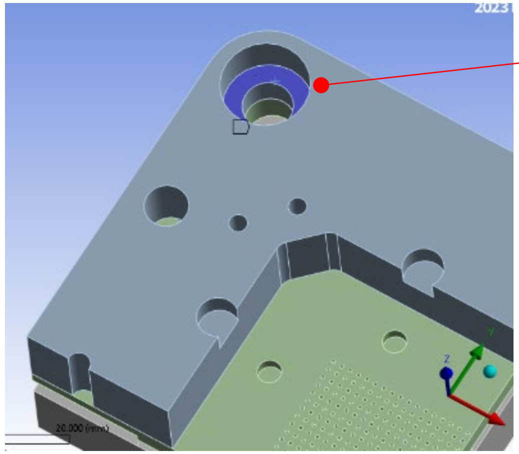
ANSYS Model setup

- Frame part
  - Stiffness Behavior: Flexible
  - Material: 6061 Aluminum
  - Bolt hole surface: Fixed support



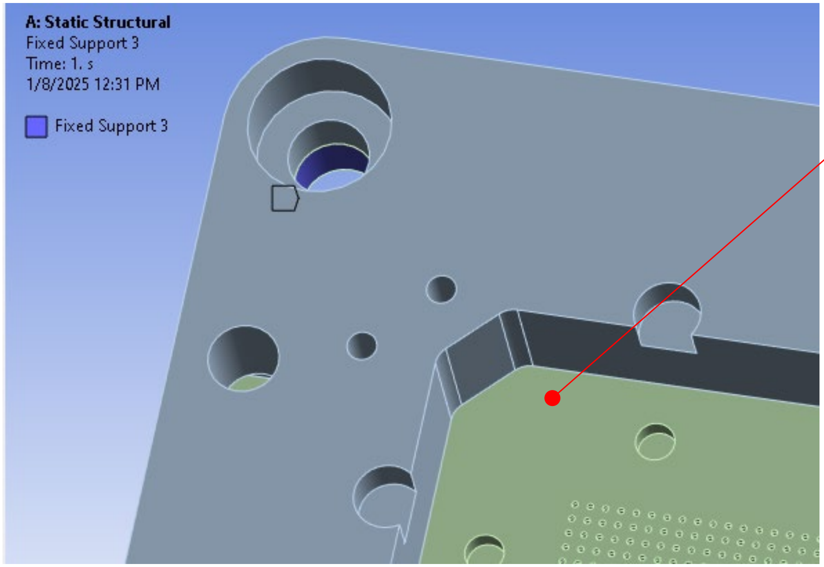
Graphics Properties	
Definition	
Suppressed	No
ID (Beta)	23
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Aluminum 6061-T651
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Statistics	

Details of "Fixed Support 2"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
ID (Beta)	55
Type	Fixed Support
Suppressed	No

ANSYS Model setup

- Housing part
  - Stiffness Behavior: Flexible
  - Material: MDS-100
  - Bolt hole ID surface: Fixed support (to prevent rigid body motion)

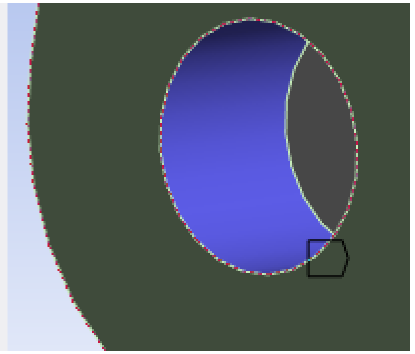


Details of "bowing_314579-0001-1"

Graphics Properties	
Definition	
Suppressed	No
ID (Beta)	26
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	MDS 100 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Statistics	

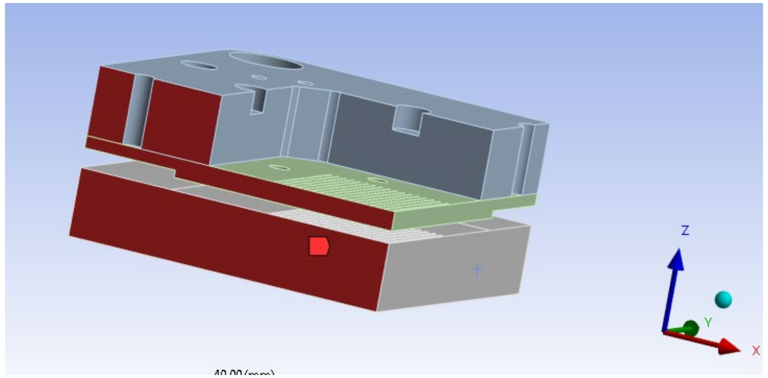
Details of "Fixed Support 3"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
ID (Beta)	156
Type	Fixed Support
Suppressed	No



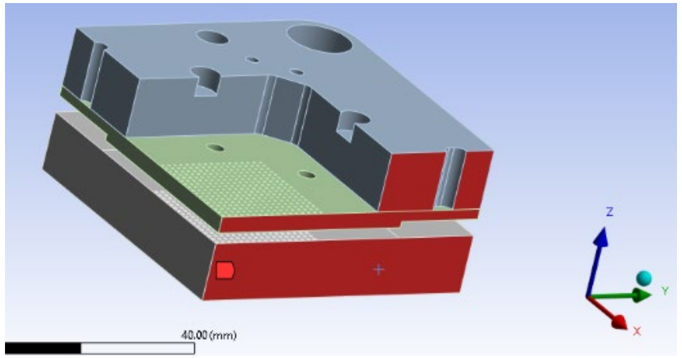
Define Symmetry

- X-Z Symmetry plane



Details of "Symmetry Region"	
Scope	
Scoping Method	Named Selection
Named Selection	XZsurface
Definition	
Scope Mode	Manual
Type	Symmetric
Coordinate System	Global Coordinate System
Symmetry Normal	Y Axis
Suppressed	No

- Y-Z Symmetry plane



Details of "Symmetry Region 2"	
Scope	
Scoping Method	Named Selection
Named Selection	YZsurface
Definition	
Scope Mode	Manual
Type	Symmetric
Coordinate System	Global Coordinate System
Symmetry Normal	X Axis
Suppressed	No

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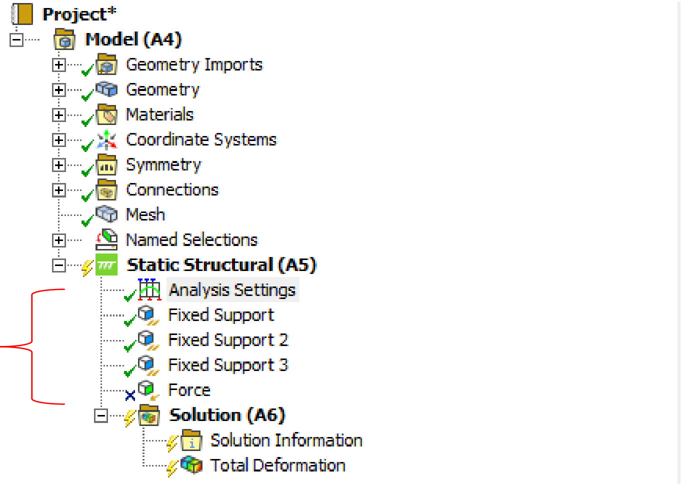
General Analysis Setup

Fixed Supports define the constraints



Large Deflection: ON

(iterative analysis for accuracy)

Details of "Analysis Settings"

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	On
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Restart Controls	
Nonlinear Controls	
Advanced	
Output Controls	
Analysis Data Management	
Visibility	

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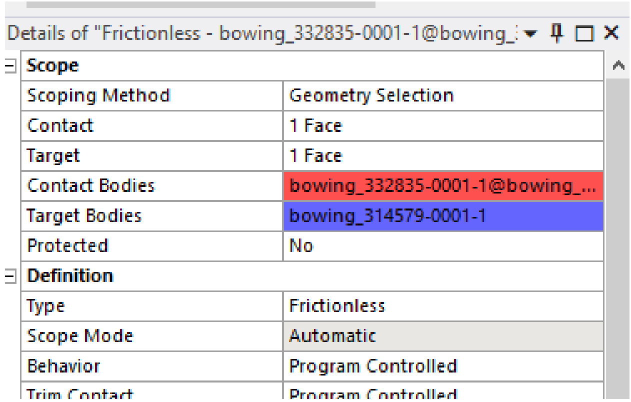
Connections – Surface Contacts

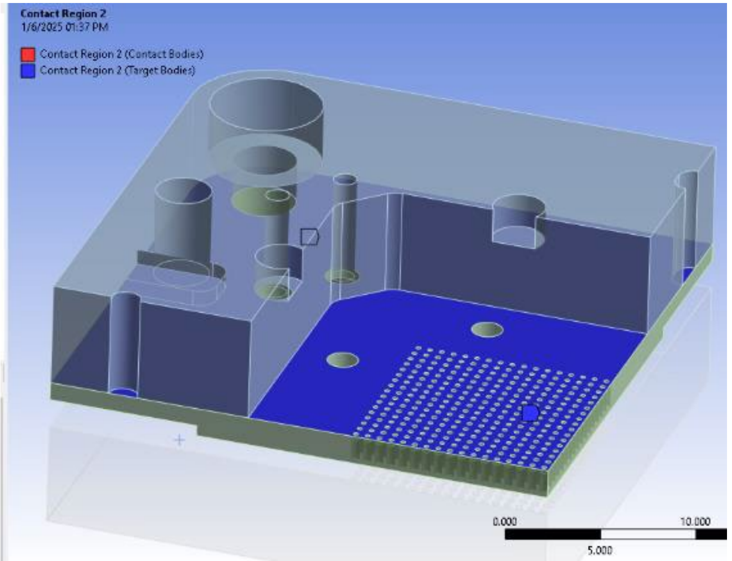
- Frame and Housing contact region: Frictionless (allows for part separation but not interference)

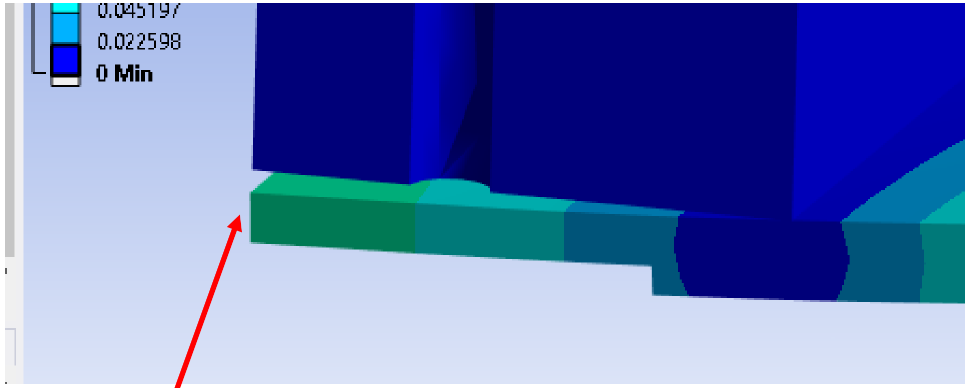
  Note: default is bonded. Change this value from “Bonded” to “Frictionless”.



Details of "Frictionless - bowing_332835-0001-1@bowing_

Scope	
Scoping Method	Geometry Selection
Contact	1 Face
Target	1 Face
Contact Bodies	bowing_332835-0001-1@bowing_...
Target Bodies	bowing_314579-0001-1
Protected	No
Definition	
Type	Frictionless
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled



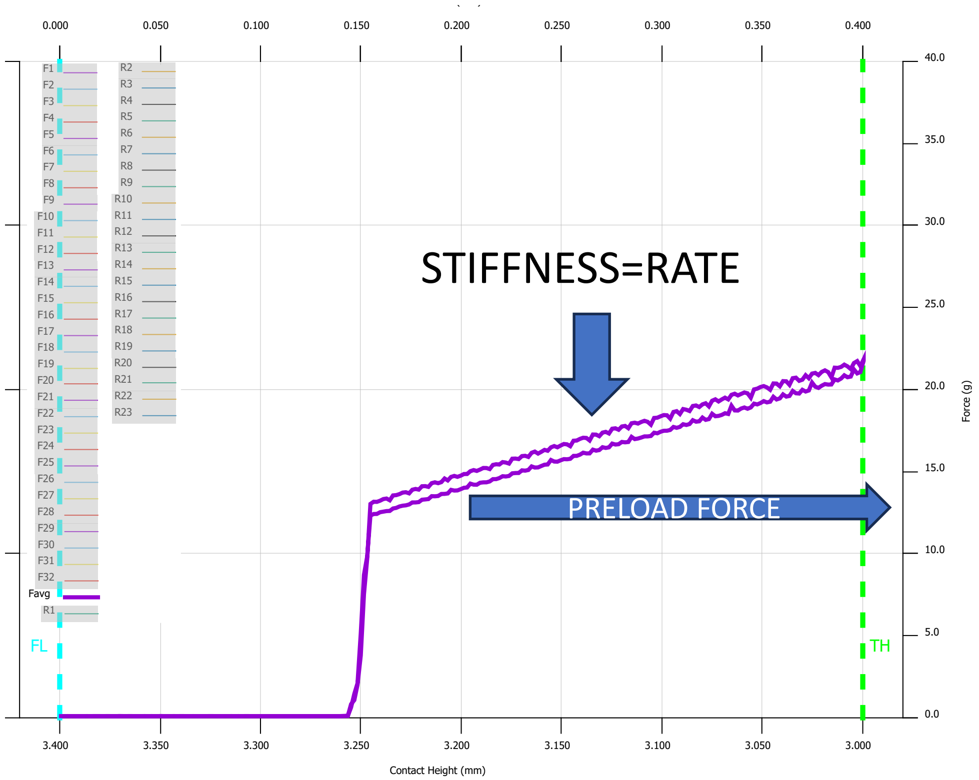


Allows for separation (based on design)

Determine the Probe Preload

Profile the spring probe to capture the spring rate k and probe preload.

$$F_x = F_{preload} + kx$$



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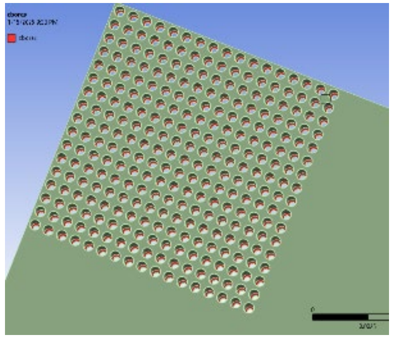
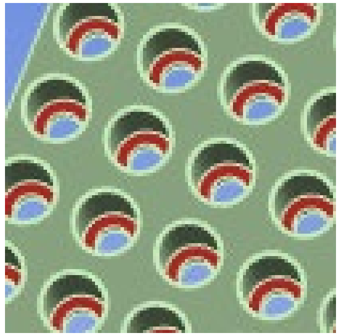
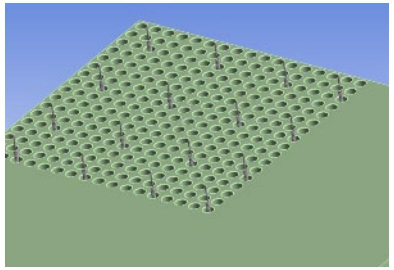
Force Application Methods In ANSYS

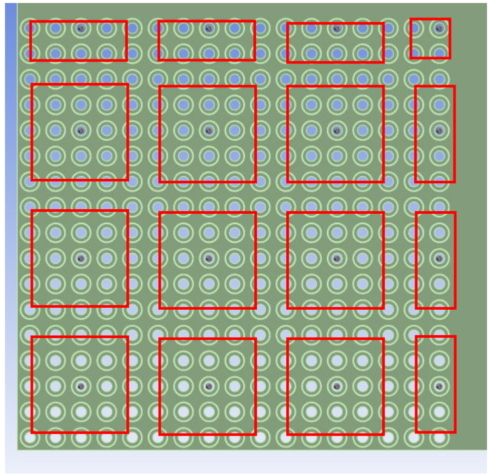
- Static Structural Force
  - Applies a single force uniformly over the selected probe-bearing surfaces
  - Quick to setup and run
  - Safe - Overstates the deflection
  - “Pass” provides approval of design
  - “Fail” requires Spring Elements Method





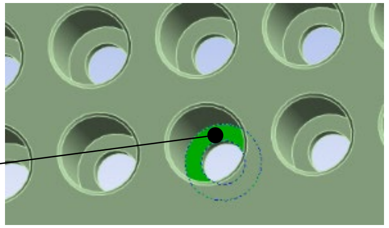
- Spring Elements Method
  - Applies spring elements between the housing and the board to simulate spring probe preload.
  - Single spring elements are spaced in maximum 5x5 arrays.
  - More time consuming
  - Accurate within 10 µm



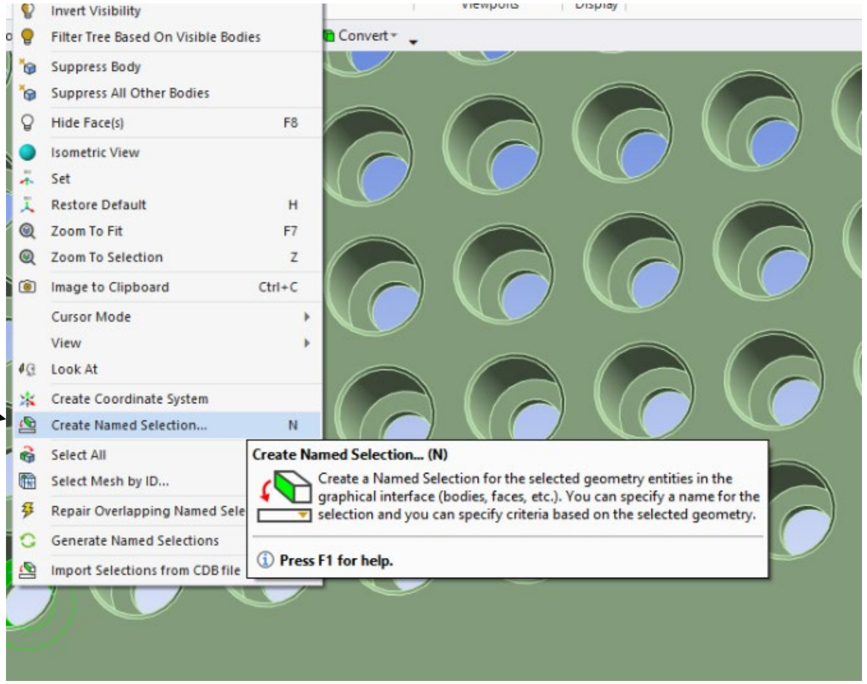


Static Structural Force Method
Step 1: Define the Probe Bearing Surface

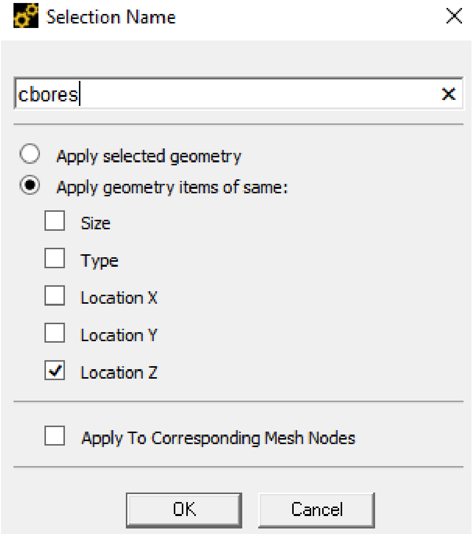
1. Define the housing probe bearing surface by selecting a <u>single probe bearing surface</u>.



2. Right click and select “Create Named Selection”.



3. Provide a name and “Apply geometry items of same: Location Z”.



4. Press OK.

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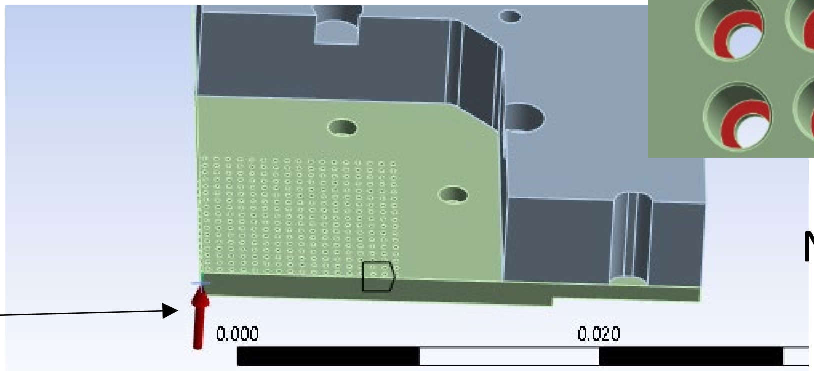
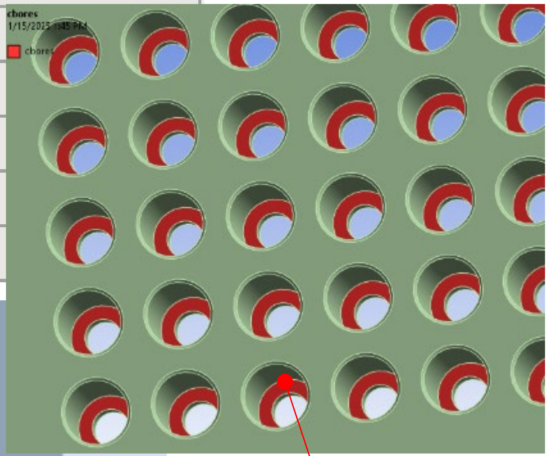
Static Structural Force Method
Step 2: Apply the Total Preload to the Housing

1. Right Click on Static Structural->Insert->Force
2. Scoping Method = "Named Selection" and Named Selection to be the name of probe bearing surface from Step 1.3.
3. Define by = "Vector"
4. Applied By: Surface Effect
5. Magnitude = Preload x Bores
6. Direction normal to surface of housing.

Details of "Force"

Scope	
Scoping Method	Named Selection
Named Selection	cbores
Definition	
Type	Force
Define By	Vector
Applied By	Surface Effect
Magnitude	17.05 N (ramped)
Direction	Click to Change
Suppressed	No





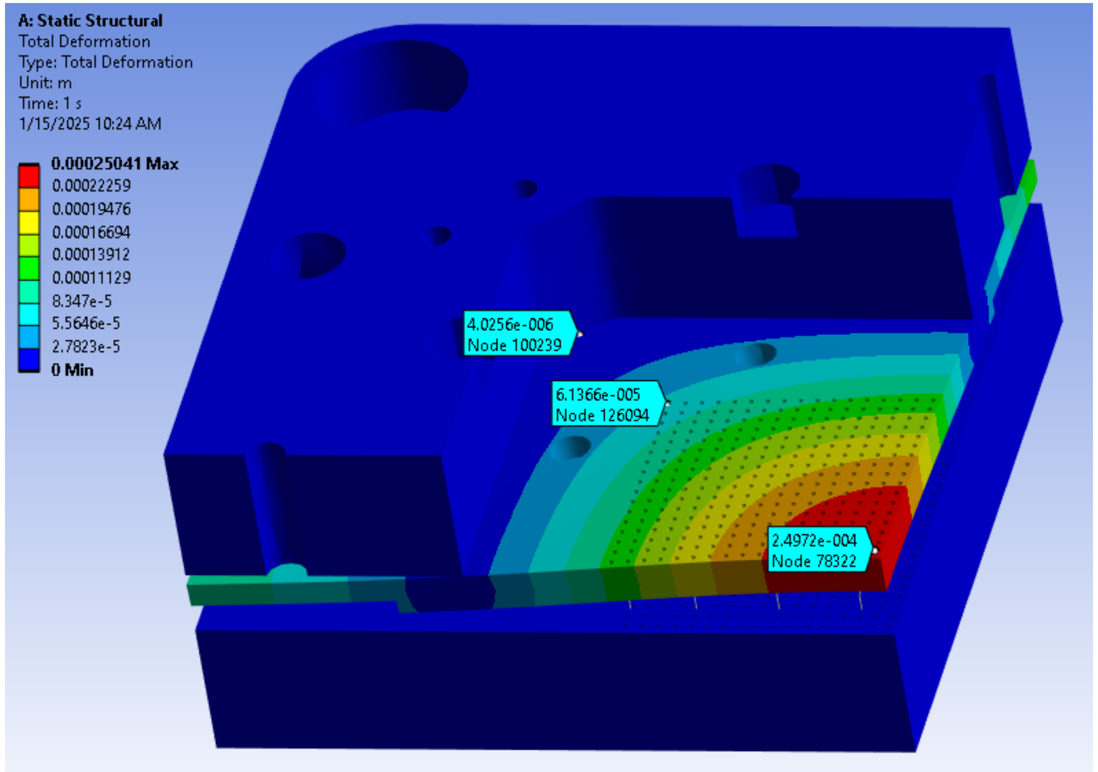
Static Structural Force Method
Step 3: Run Simulation and Probe Results

- Preload 6gm (0.059N)
  - 289 x 0.059N = 17.05N
- Center deflection = 0.170mm

FAIL > 0.150mm deflection

<u>Conclusion</u>

- Proceed with Spring Elements Model for more accurate analysis



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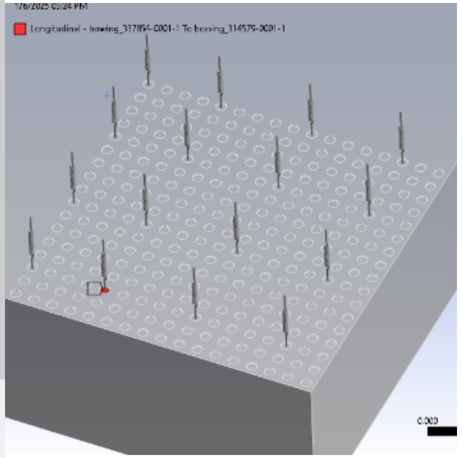
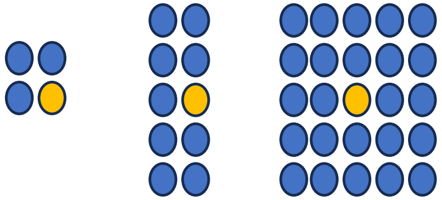
Spring Elements Model

- Contact regions derived using compression-only spring elements
- Add spring stiffness constant (N/mm) and nominal preload (N)

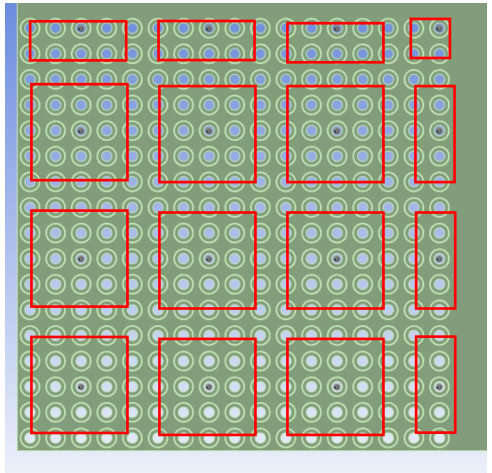
Graphics Properties	
Definition	
Material	None
Type	Longitudinal
Spring Behavior	Compression Only (Beta)
Longitudinal Stiffness	8.5875 N/mm
Preload	Load
Load	-1.8975 N
Suppressed	No
Spring Length	2.385 mm
Element APDL Name	
Scope	
Scope	Body-Body
Reference	
Scoping Method	Geometry Selection
Applied By	Remote Attachment
Scope	1 Face
Body	bowing_337854-0001-1
Coordinate System	Global Coordinate System



- To save time – add elements in 5x5 arrays or smaller



2x2 2x5 5x5



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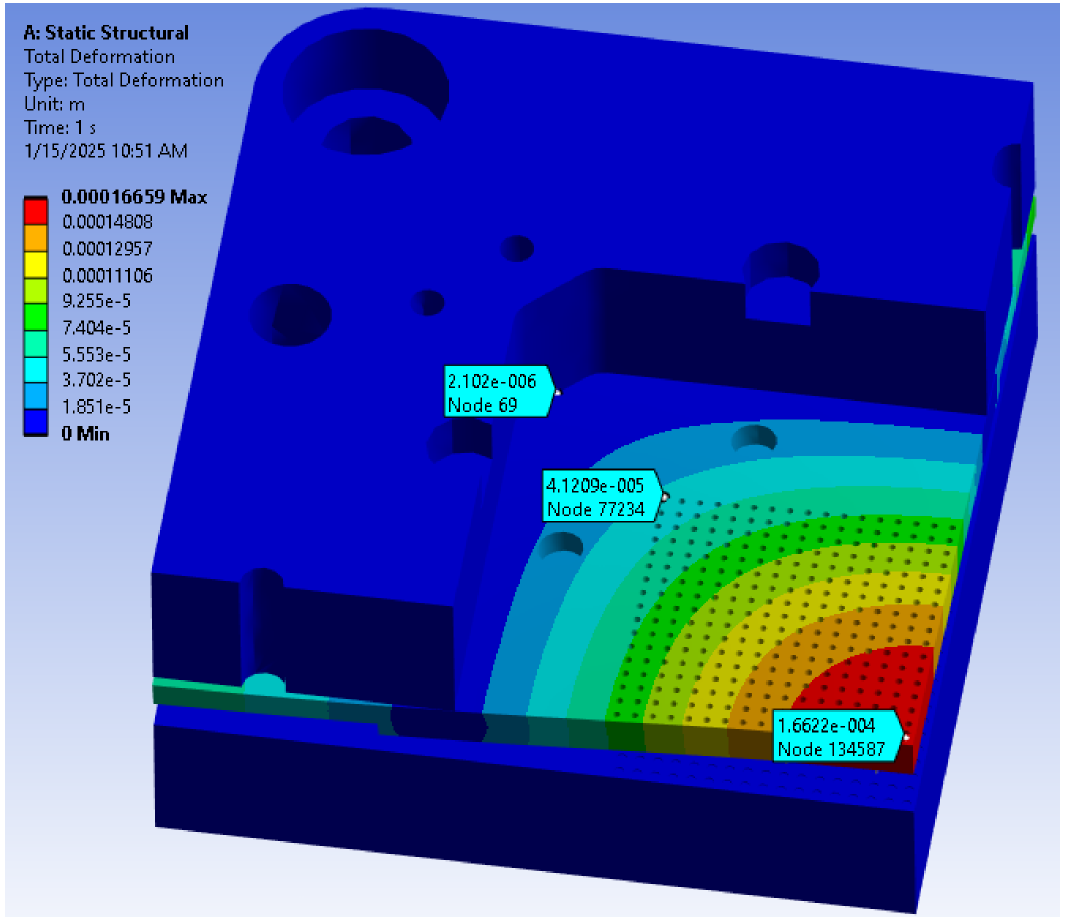
Preload = 6gm (0.059N)



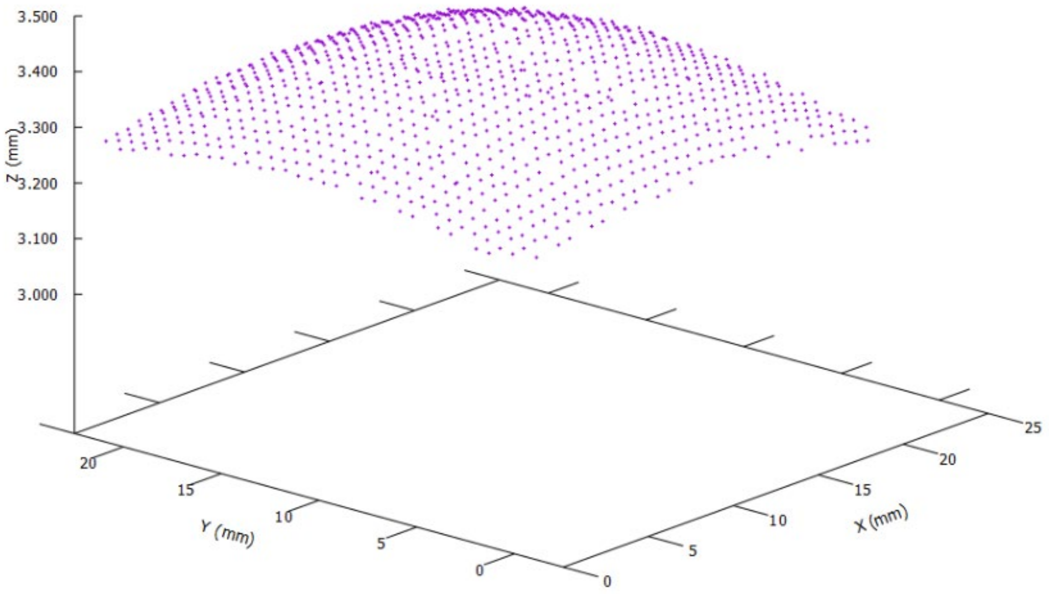
- Preload 6gm (0.059N)
  - 5x5 = 1.47 N preload
  - 2x5 = 0.59 N preload
  - 2x2 = 0.24 N preload
- Center deflection = 0.098mm

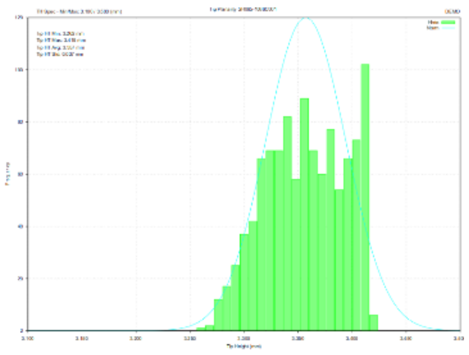
PASS < 0.150mm

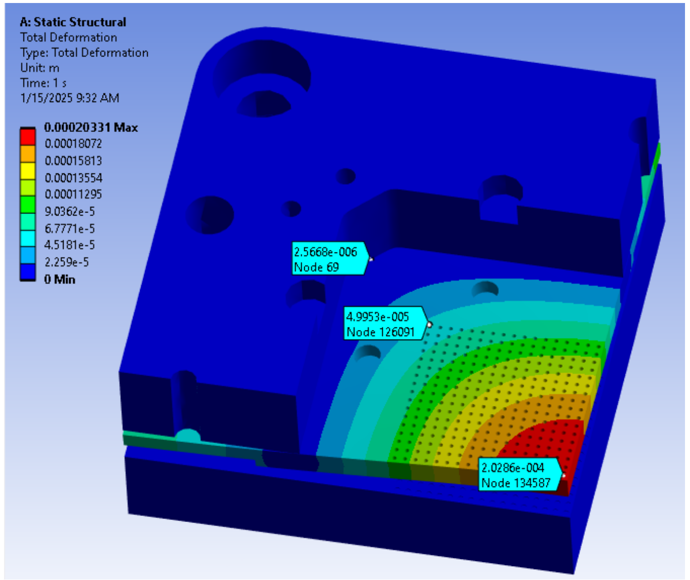
Is this simulation accurate?

Am I able to increase the preload of this probe within this design?

Validation Results on 12 gm Preload







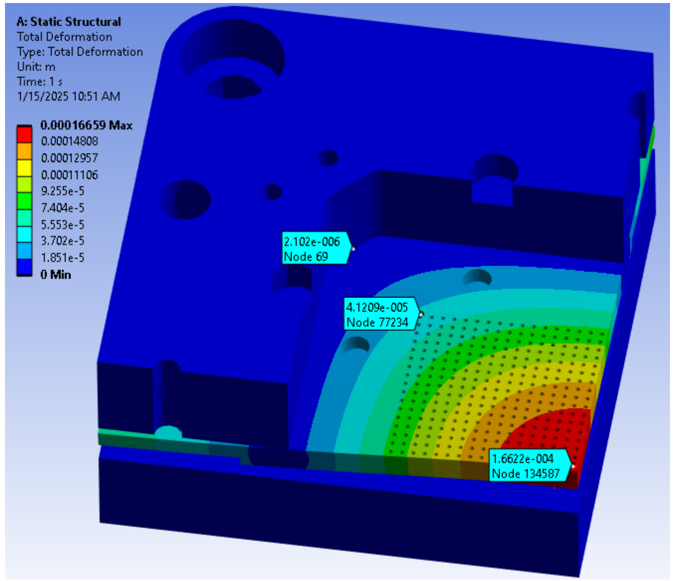
Center array to corner Max-Min

Measured: 0.156mm

Simulated: 0.153mm

Good match!

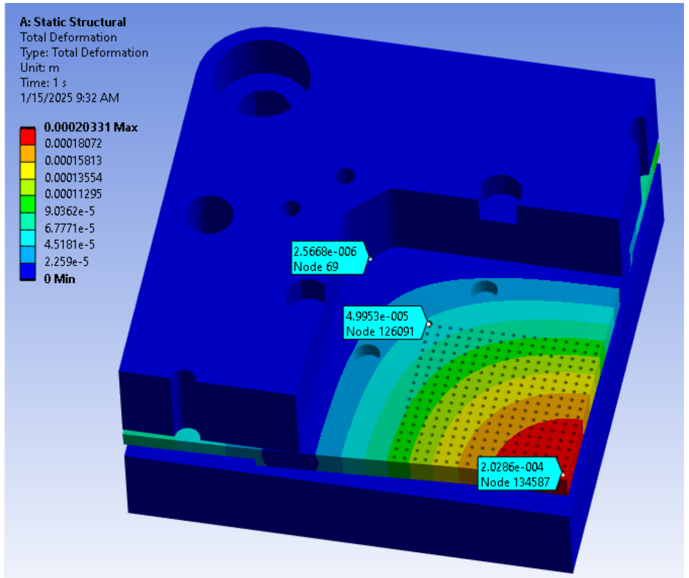
Increase Preload



- Preload 10gm (0.098N)
  - 5x5 = 2.45 N preload
  - 2x5 = 0.98 N preload
  - 2x2 = 0.39 N preload

<u>Center deflection</u>

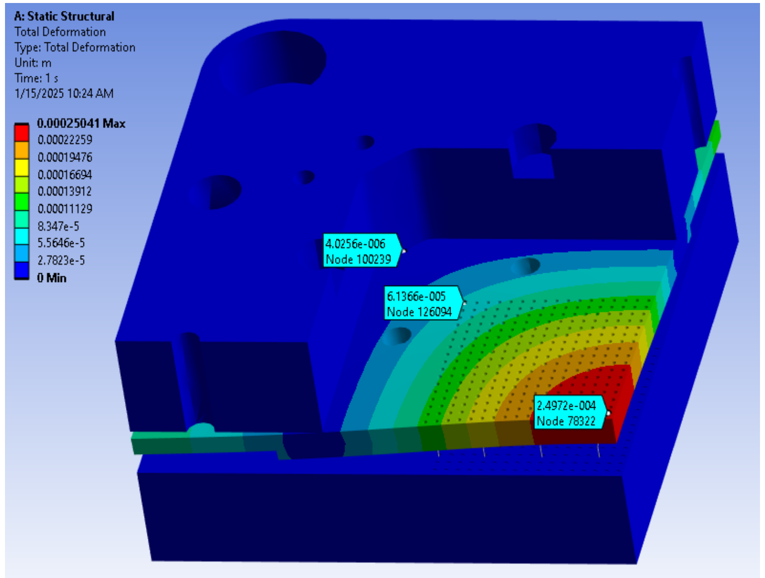
0.164mm



- Preload 12gm (0.119N)
  - 5x5 = 2.99 N preload
  - 2x5 = 1.19 N preload
  - 2x2 = 0.48 N preload

<u>Center deflection</u>

0.200mm



- Preload 15gm (0.147N)
  - 5x5 = 3.68 N preload
  - 2x5 = 1.47 N preload
  - 2x2 = 0.59 N preload

<u>Center deflection</u>

0.246mm

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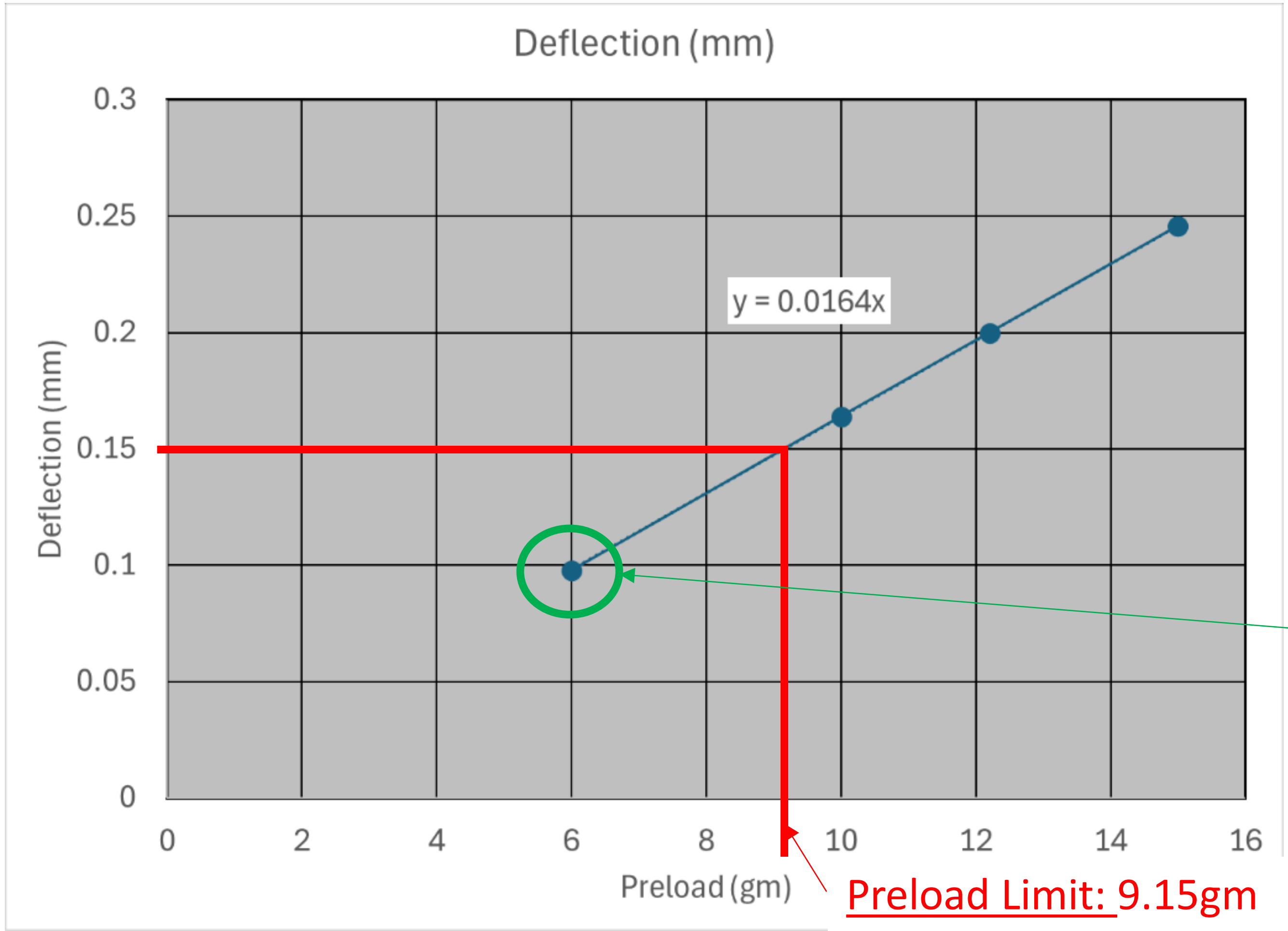
Case Study with Shoto® Conclusion



Preload Limit: 9.15gm

The curve crosses the 0.15mm deflection at 9.15gm.

Conclusion: For this probe in a 1156 configuration, It is recommended that the preload be designed to be < 9gm.

The selected probe with 6gm preload is acceptable for this design.

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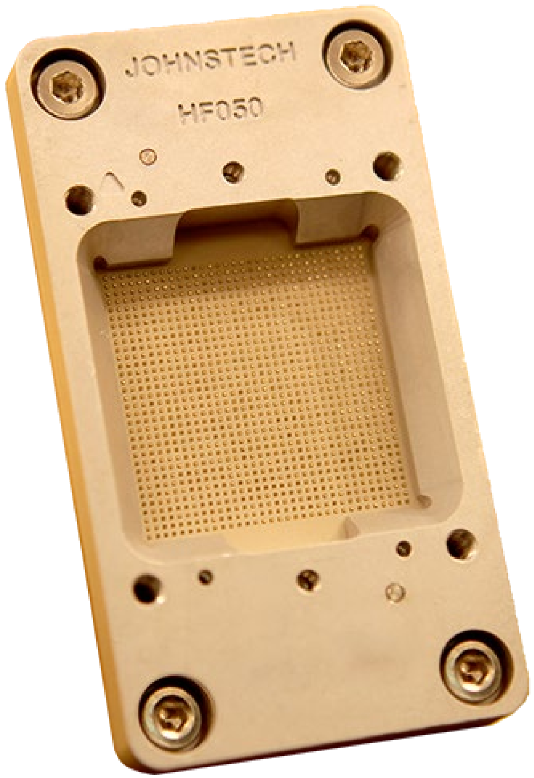
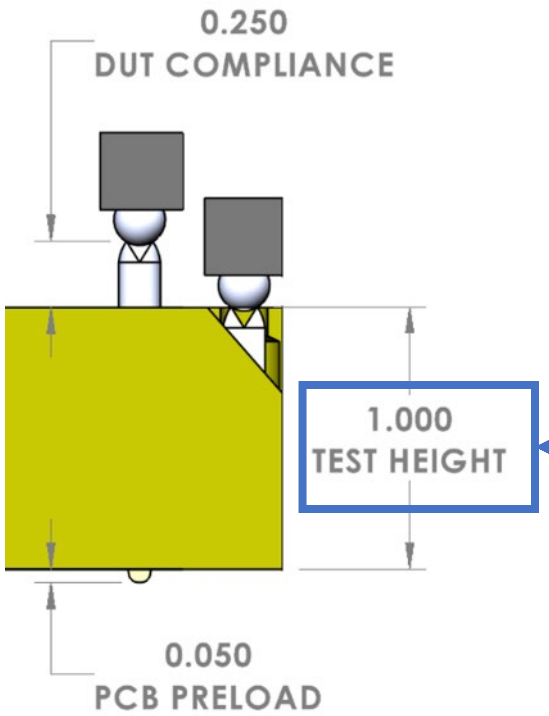
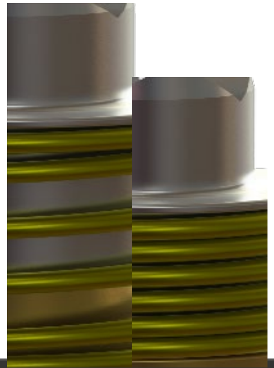
HERØ HF™ Short Contact w/ High Pin Count







Contactor construction

- Standard CNC machined housing components for quick fabrication – no special tooling required
- BGA / LGA / QFN – any configuration
- Spear or crown tip probe option available

Probe

- Individually user replaceable
- Cleanable Pd alloy – inline or manual cleaning
- Patent-pending innovative probe architecture

Challenge: Achieving preload with a much thinner housing at 1.00mm test height

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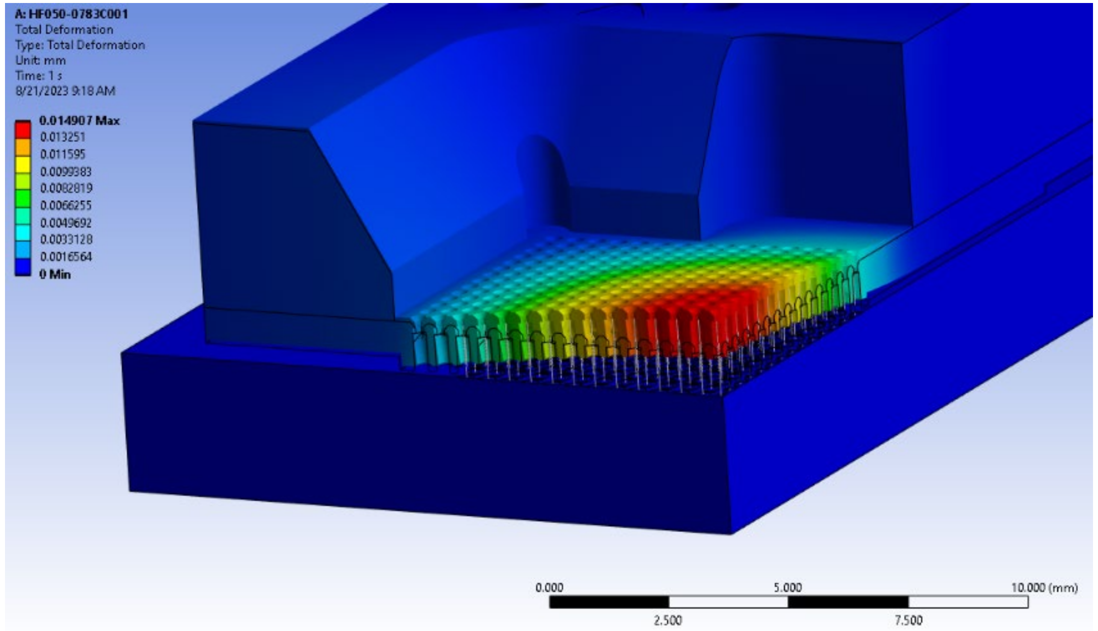
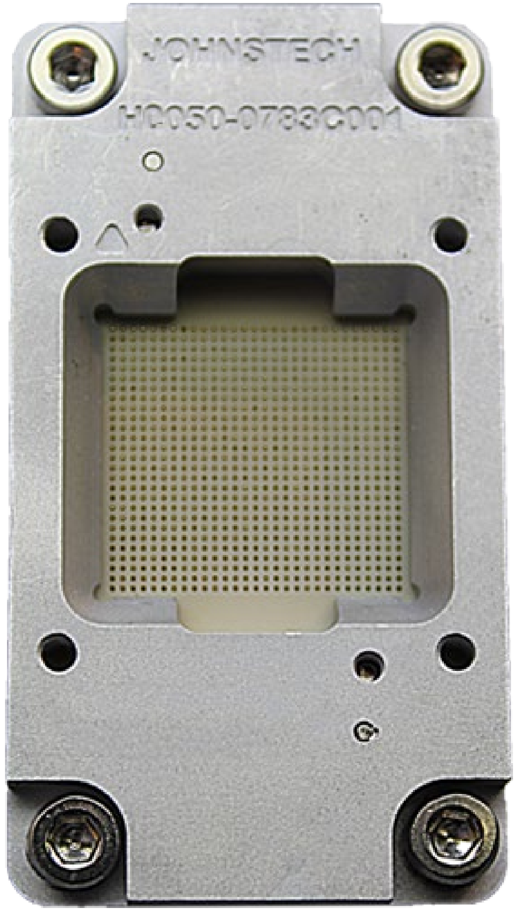


- 783 HERØ HF™ Probes
- 15x15mm package
- Center deflection = 0.015mm

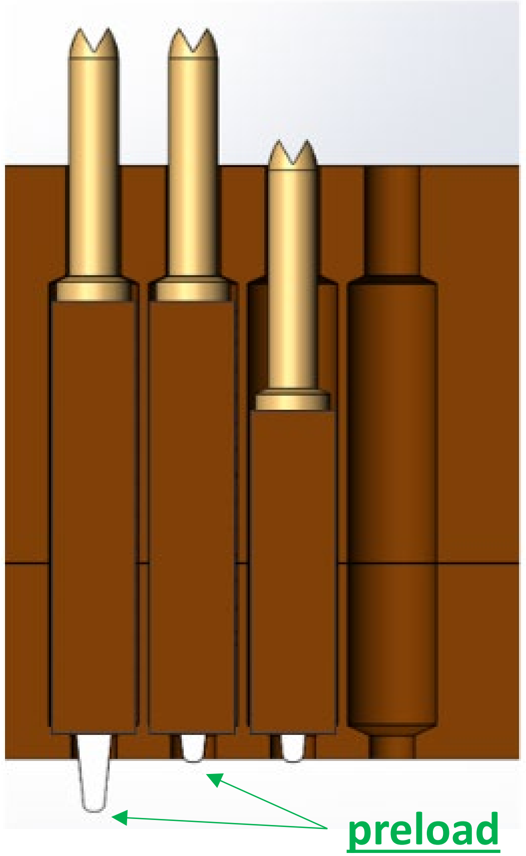
HERØ HF™ is well designed for large arrays requiring high data rates.

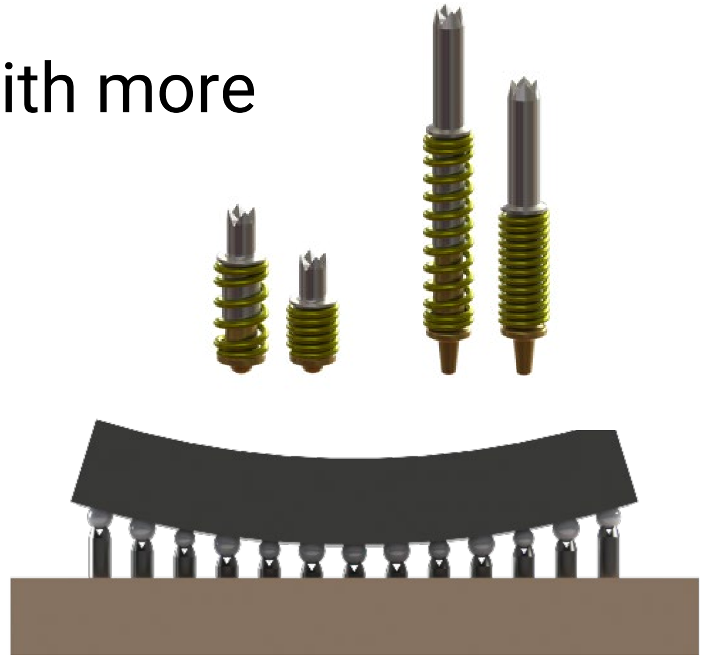
HERØ HC™ High Compliance w/ High Pin Count



Contactor construction

Same as HERØ HF™ yet with more compliance





HERØHC™ is designed with a compliance range to overcome warpage challenges

Up to 0.75mm of travel to final test height of 2.5mm

Challenge: Achieving preload with a much larger packages and higher ball counts.

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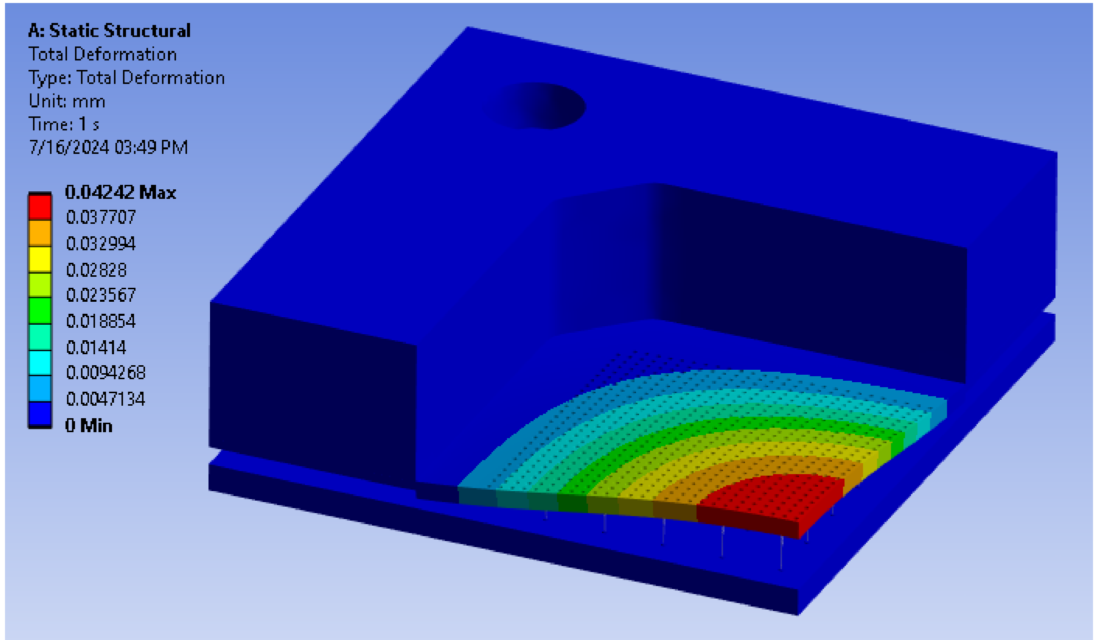
HERØ HC™ High Compliance w/ High Pin Count



- 2916 HERØ HC™ Probes
- 55x55mm package
- Center deflection = 0.042mm

Even though larger arrays will inherently lead to higher deflections, the HERØ HC™ can provide extra compliance to ensure proper preload.

Summary

- For large device AI applications, mechanical simulations can aid in the design of the contactor with the right probe and with the right preload.

1. Simplify model – remove unnecessary features and apply ¼ symmetry to speed up simulations.
2. Define materials and constraints – maintain a verified and controlled library of materials for reference.
3. Determine probe preload and spring rate – measure actual probes and use the data in the simulation.
4. Simulate deflection - Start with Static Structural Model, if needed verify with Spring Elements Model.
5. Validate simulation – measure the actual array

Thank You!

Questions?

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