



IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

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Thermal Analysis of Wafer Level Probes for Final Test

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Computational Modeling With

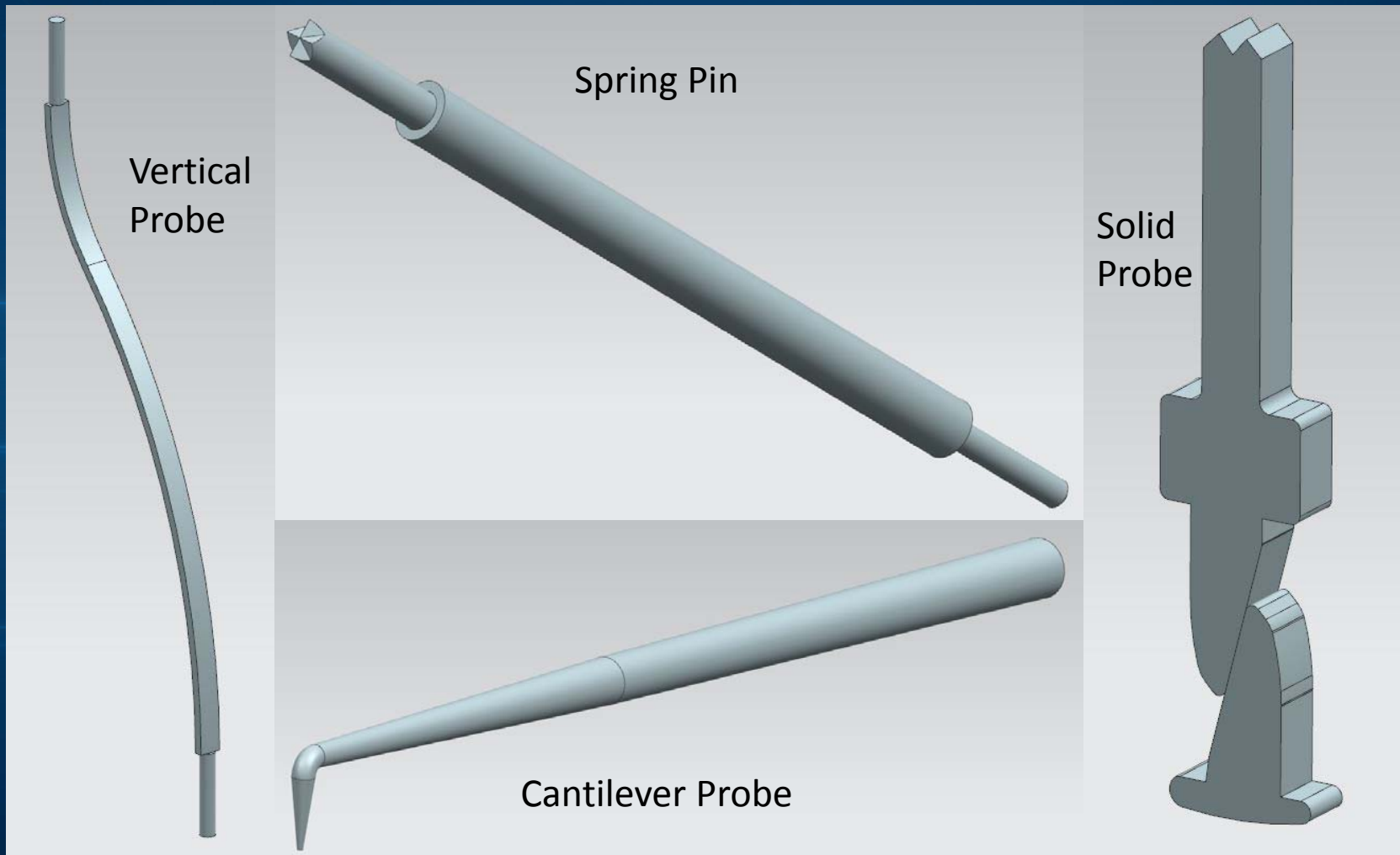
The ANSYS logo is displayed in a dark rectangular box. The word "ANSYS" is written in a bold, serif font. The letters "AN" are white, and the letters "SYS" are yellow. A registered trademark symbol (®) is located to the upper right of the letter "S".

- In this tutorial you will learn how to setup up and run a computational thermal analysis
- ANSYS ICEPAK
 - Electronics thermal management
- Joule Heating / Resistive Heating
- Computational Fluid Dynamics

Assumptions

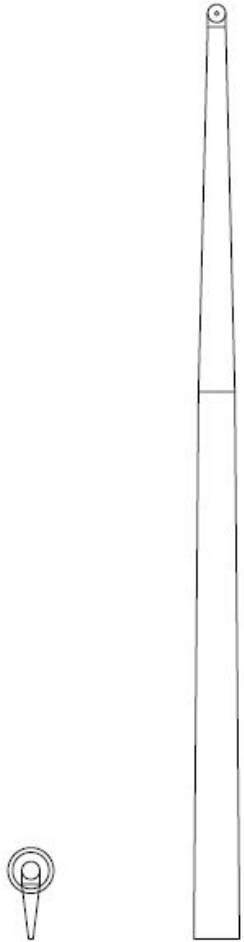
- 400 micron Pitch Probe Geometry
- Generic Probe Design
- Joule Heating Along One Axis
- Heat Sinks have constant temperature
 - 50°C DUT temp
 - 20°C LBD temp
- Material is Beryllium Copper

Probe Types

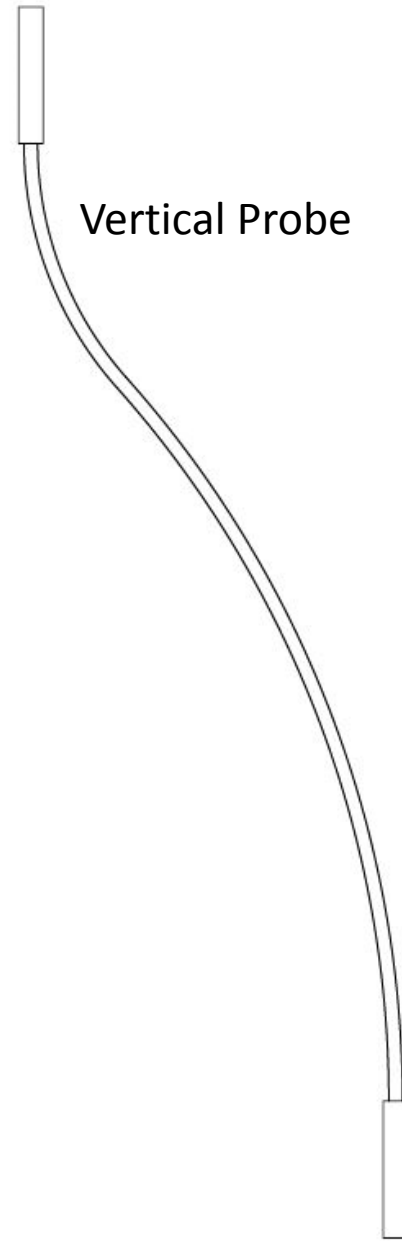


Scaled Drawing

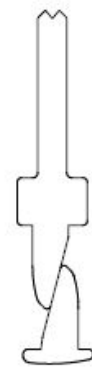
Cantilever Probe



Vertical Probe



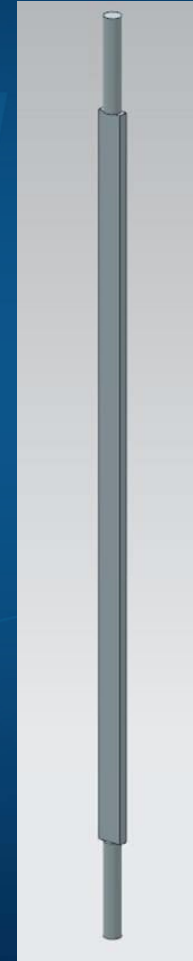
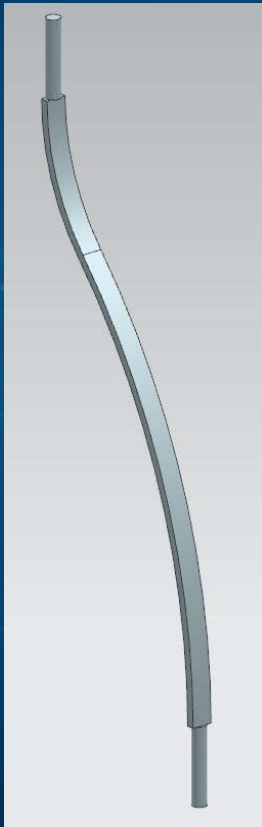
Solid Probe



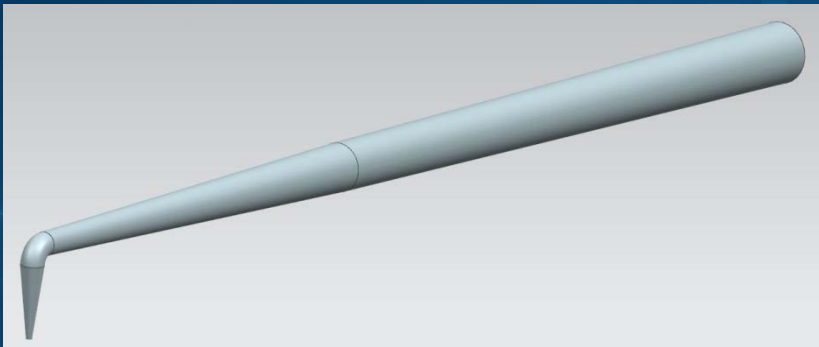
Spring Pin



Real Geometry vs. Physics Geometry

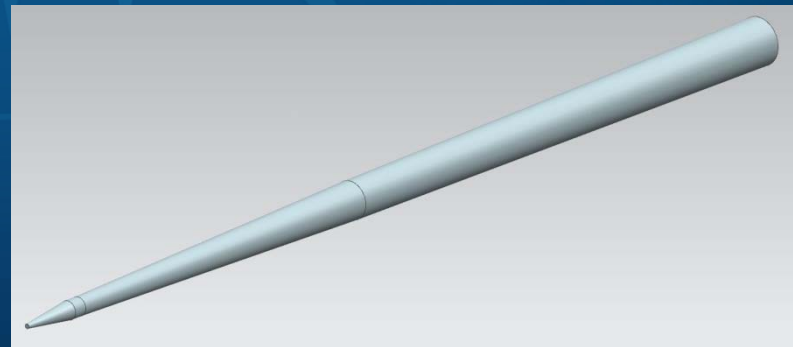


Real Geometry vs. Computational Geometry

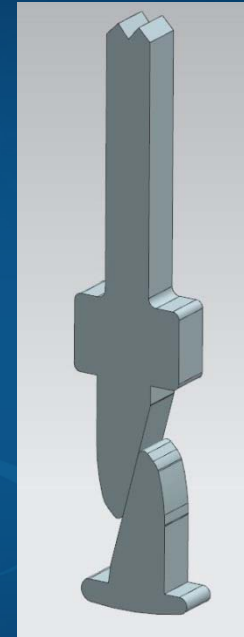
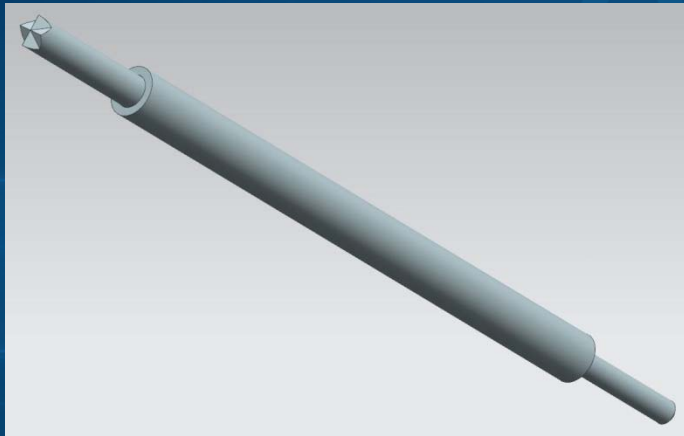


Real Geometry

Computational Geometry

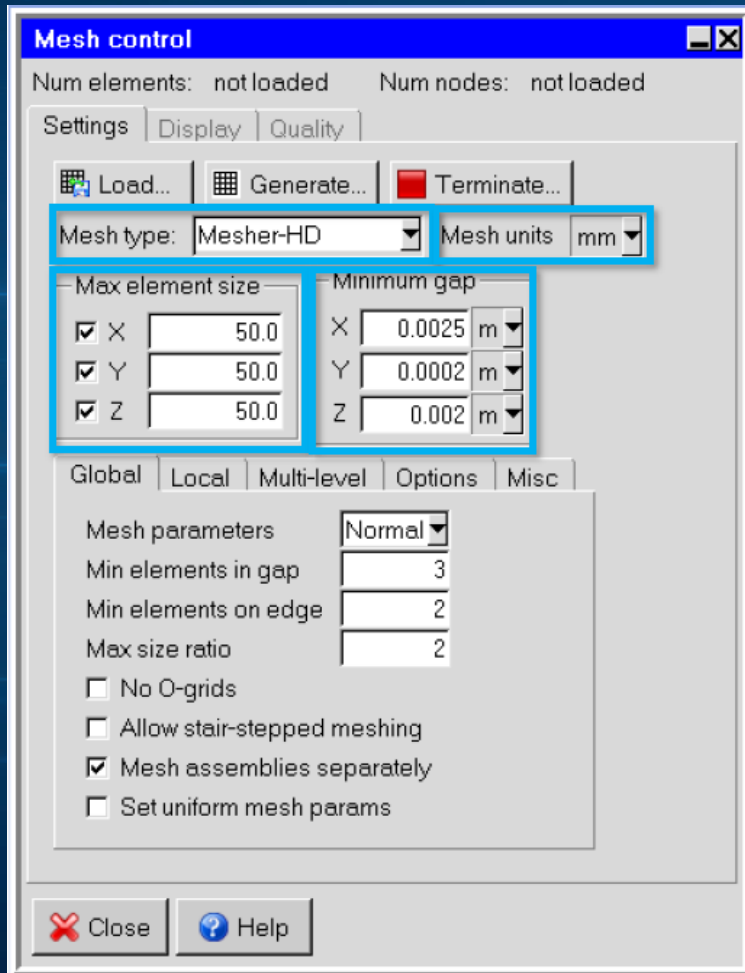


Real Geometry vs. Computational Geometry



Spring pins and solid probes all have electrons traveling in one axis and no changes are required for the computational model

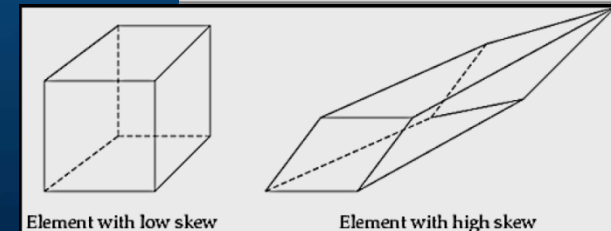
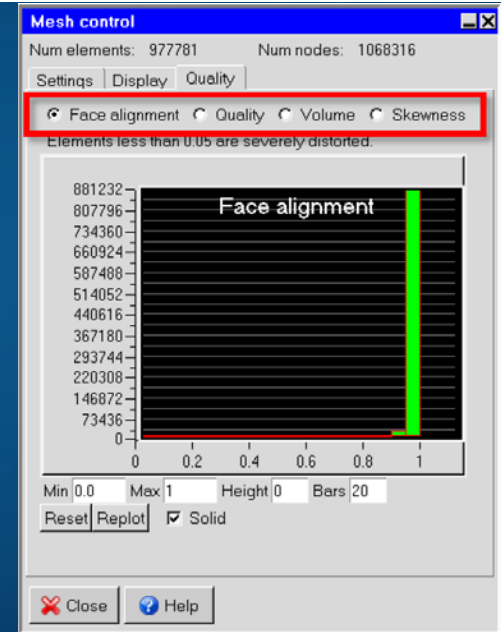
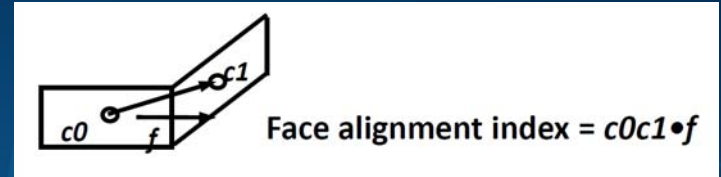
Mesh Settings



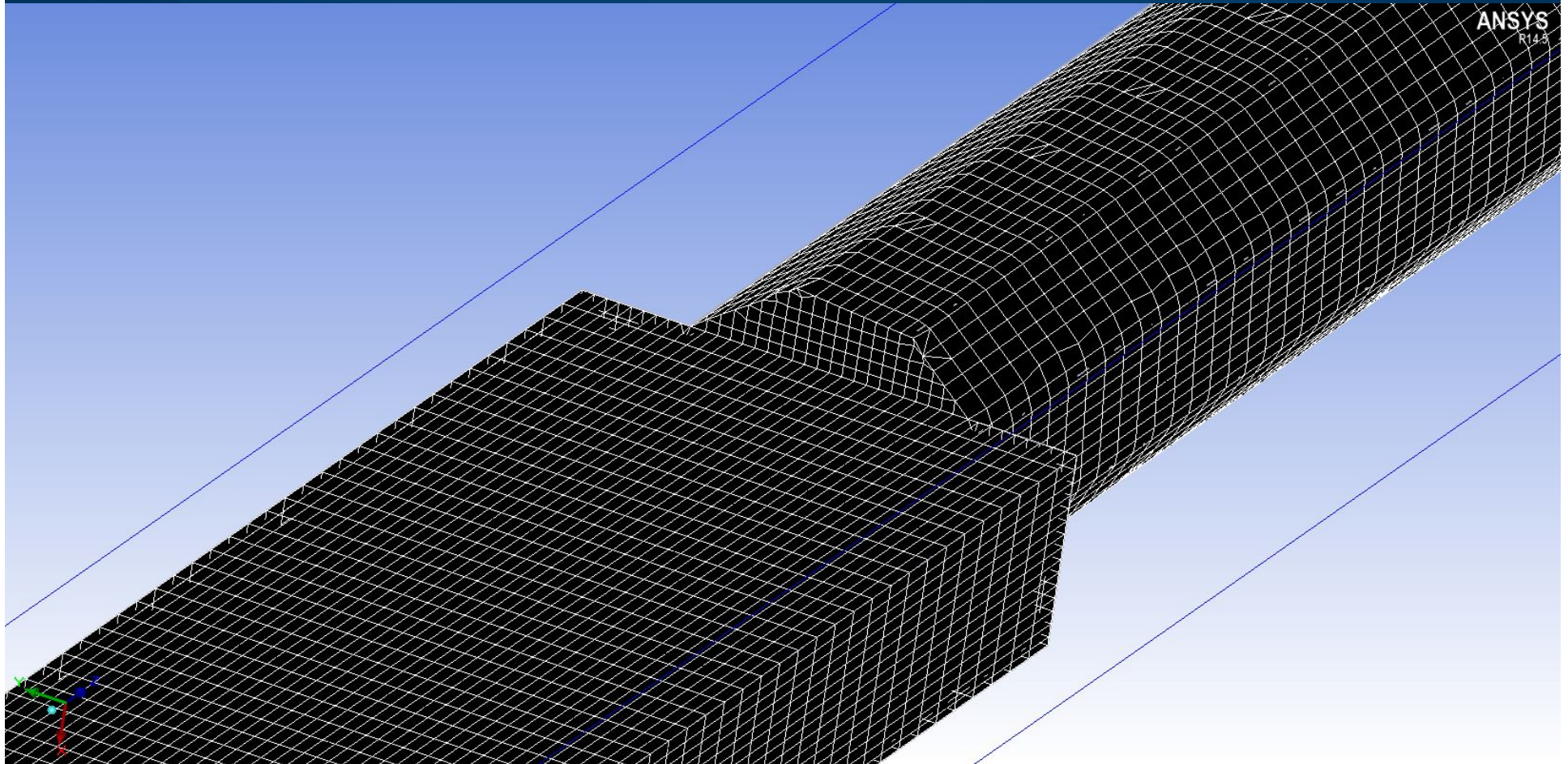
- Mesh Type
 - Mesher-HD → CAD Geometry
- Max element size
 - X, Y, and Z directional sizes of the background mesh
 - Balance between accuracy and runtime
- Minimum Gap
 - All geometries below this tolerance will be ignored by the mesher

Meshing Verification

- Face Alignment
 - Range from 0 (bad) to 1 (good)
 - Face alignment must be greater than 0.05
 - Best results above 0.15
- Volume
 - Determines if you use double or single precision solver (1e-13)
- Skewness
 - Skewness determines how close to ideal a face or cell is
 - Should be above 0.02



Visual Inspection of the Mesh



Material Properties and Joule Heating

The image shows two software windows. The left window, titled "Joule heating power", has a blue header and contains the following settings:

- Power type: Constant Varying
- Equation: $P = \text{Current}^2(\rho L/A)$ $\rho = \text{Resistivity}(1 + C(T - T_{\text{ref}}))$
- Current: 3.0 Amp Transient
- L: Z length
- Resistivity: 7.68e-008 Ohm-m
- C: 1.0
- Tref: ambient
- Low temperature: ambient
- High temperature: ambient

Below these settings is a yellow box containing material properties:

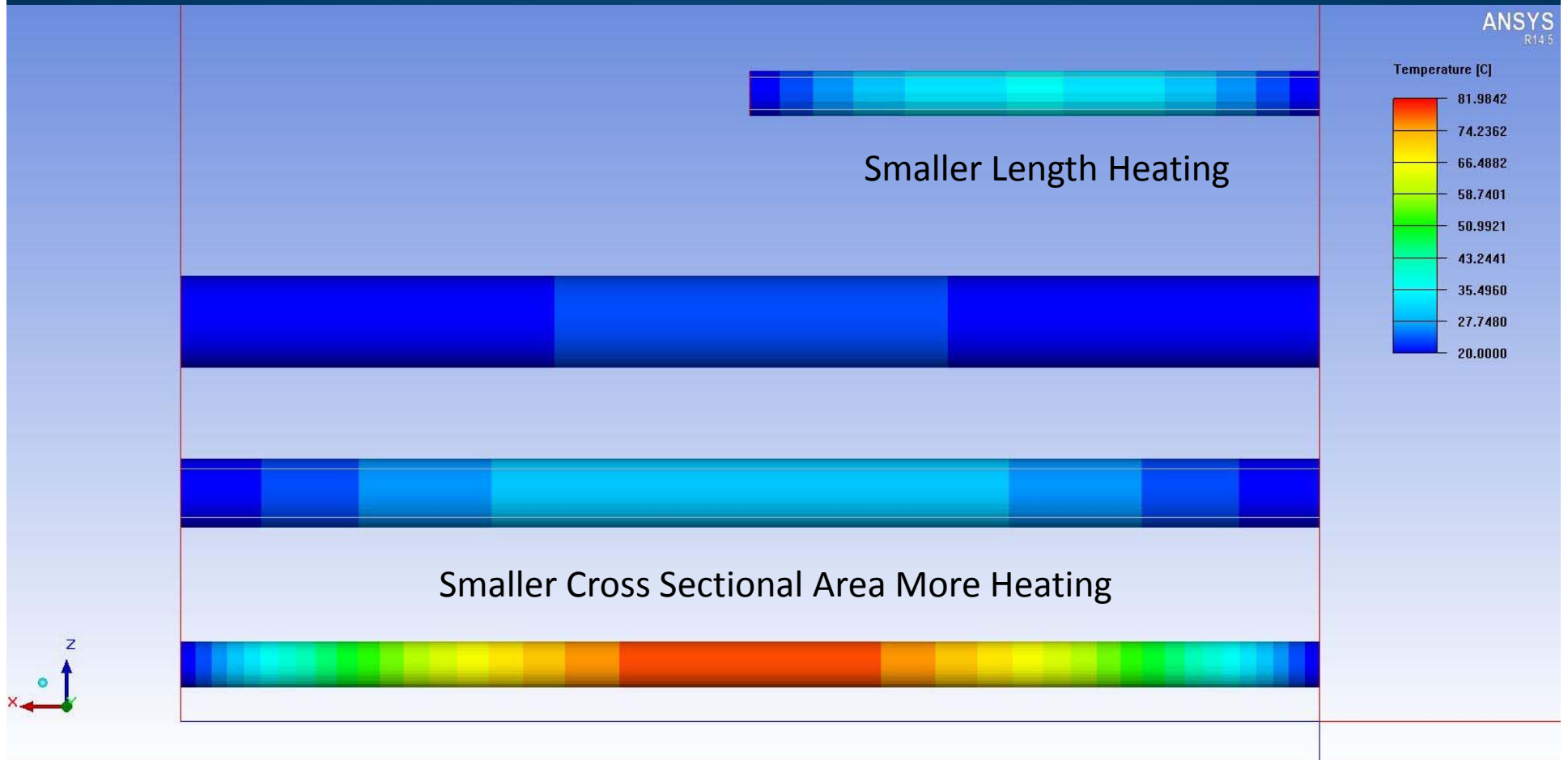
- Density = 8321.0 kg/m³
- Specific heat = 419.0 J/kg-K
- Conductivity type = Isotropic
- Conductivity = 95.0 W/m-K

The right window, titled "Blocks [Buckling Beam Flat]", has a blue header and tabs for Info, Geometry, Properties, and Notes. It is currently on the Properties tab. The settings are:

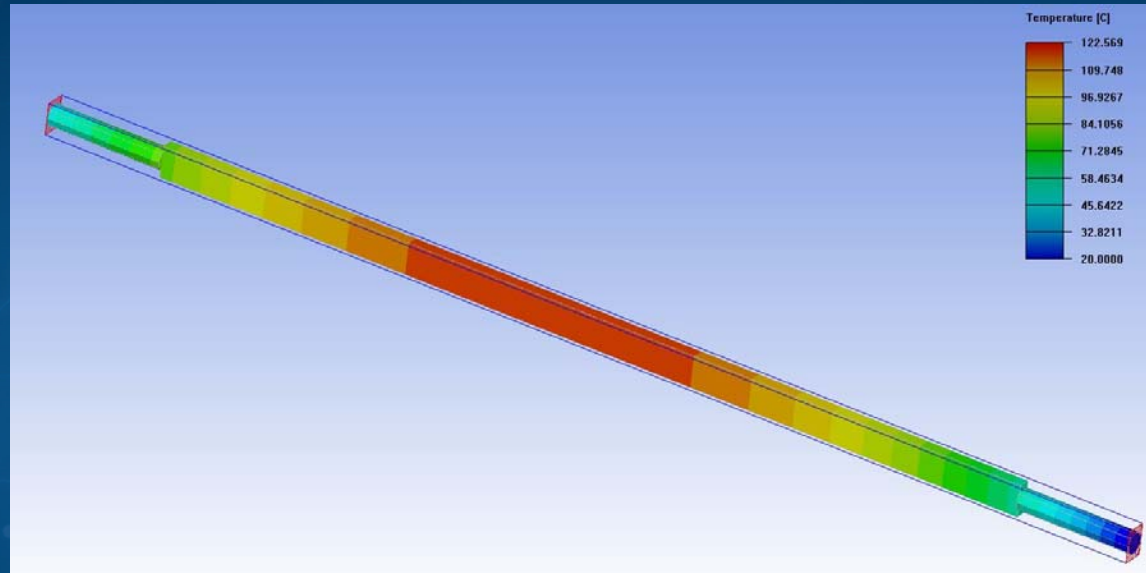
- Block type: Solid Hollow Fluid Network
- Surface specification:
 - Surface material: default
 - Area multiplier: 1.0
 - Radiation
 - Individual sides
- Thermal specification:
 - Solid material: Beryllium Copper
 - Total power: 0.0 W Joule heating
 - Rotation: 0 RPM
 - External conditions
- Temperature limit: default
- Fix values

At the bottom of the right window are buttons for Update, New, Reset, Delete, Copy from, Done, Cancel, and Help.

Joule Heating of a Physics Rod



Adding Heat Sinks

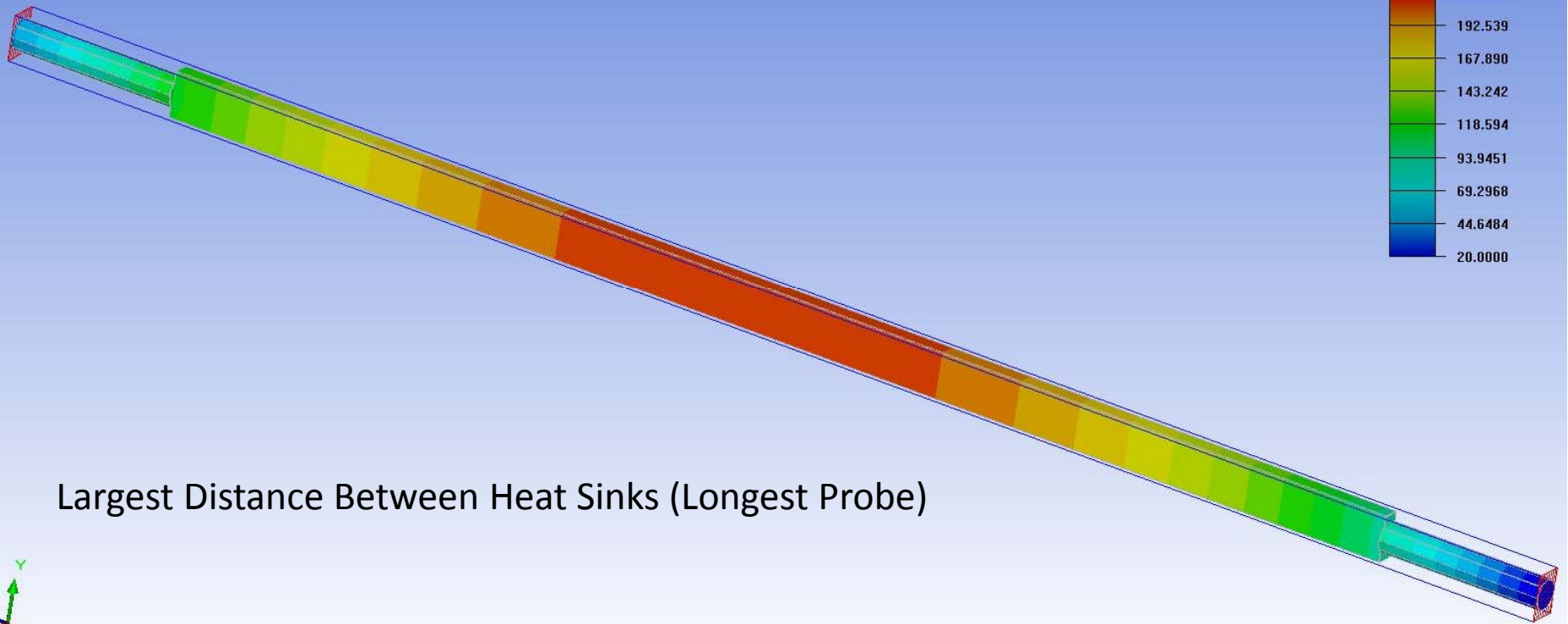
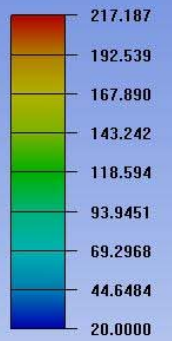


- Heat sinks being applied
 - 50°C DUT temperature
 - 20 °C Load board trace temperature

Vertical Probe

ANSYS
R14.5

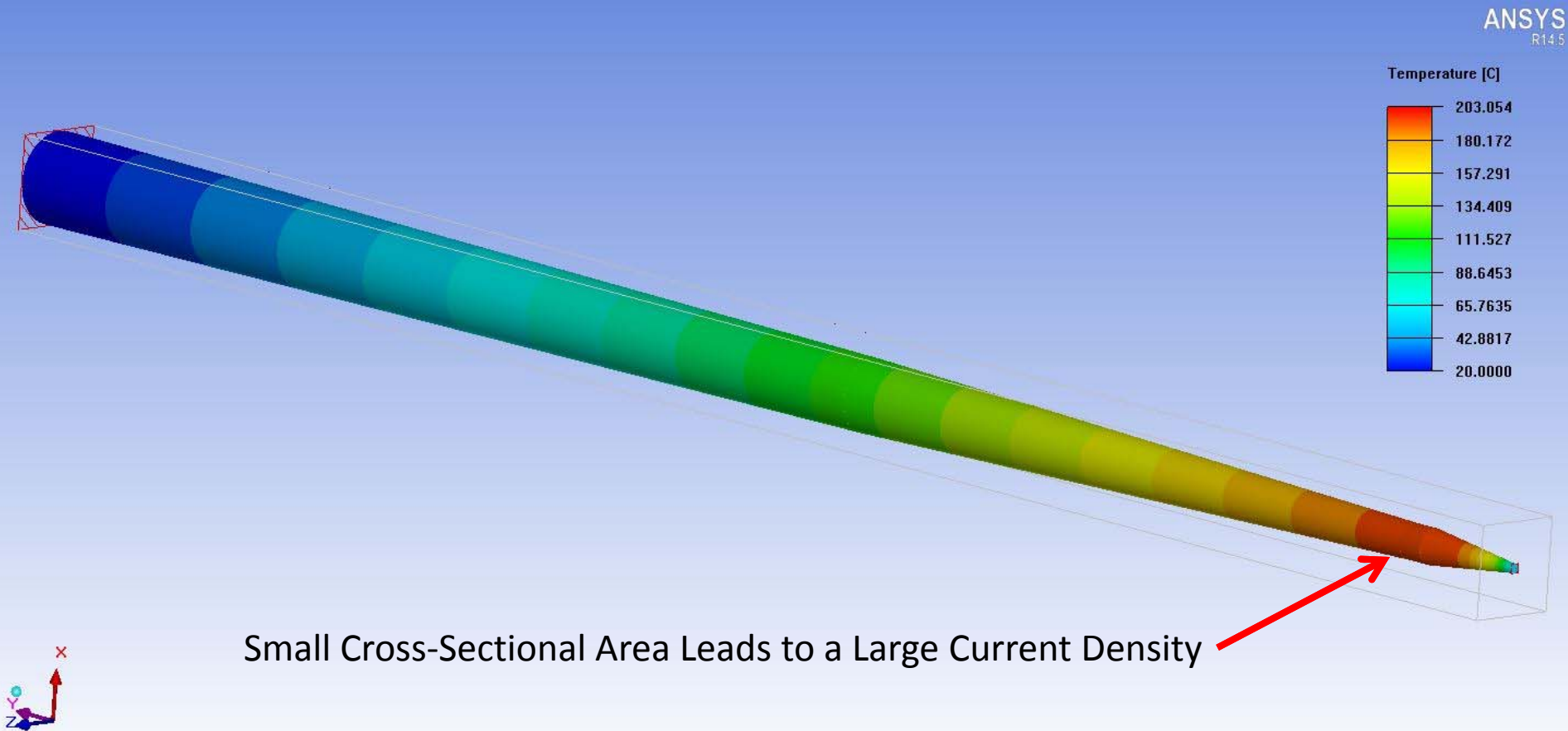
Temperature [C]



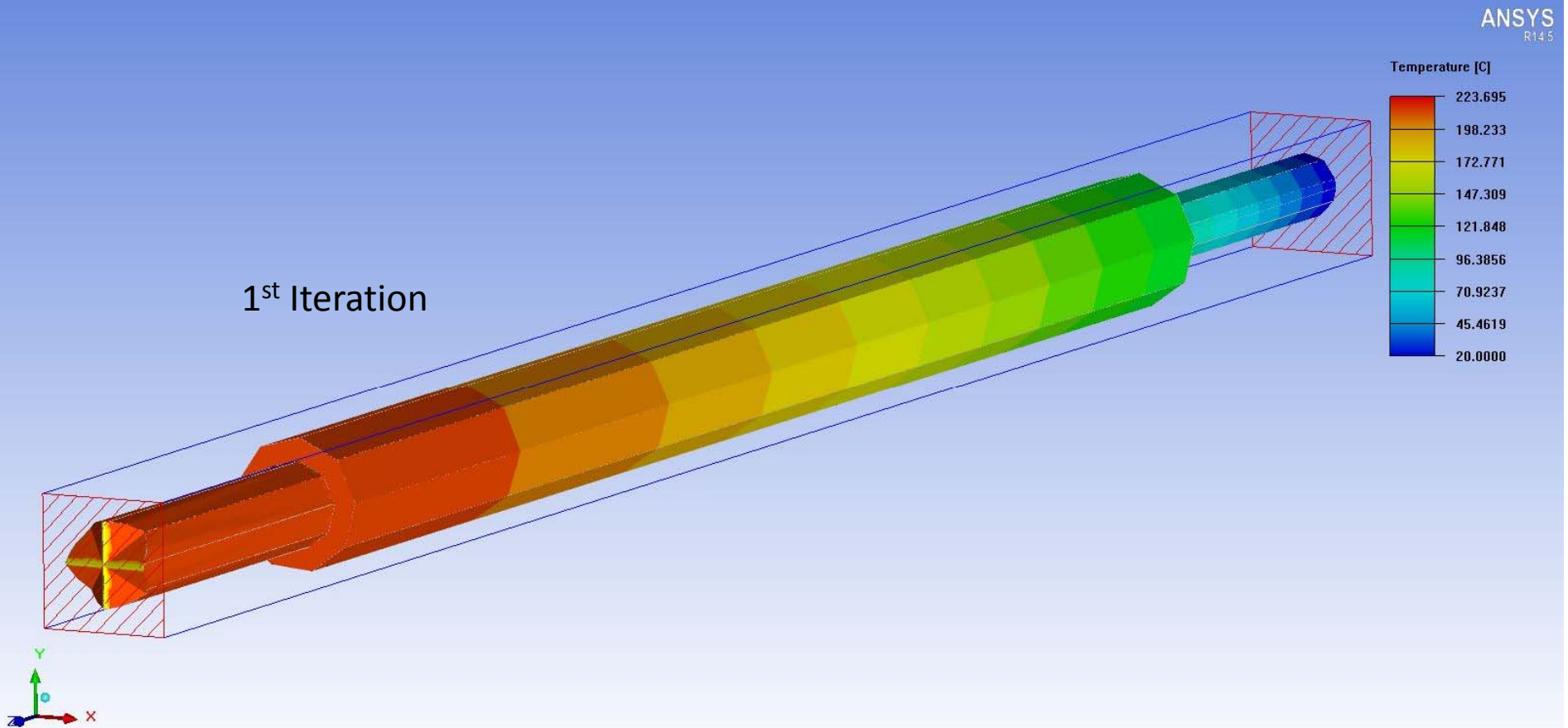
Largest Distance Between Heat Sinks (Longest Probe)



Cantilever Probe



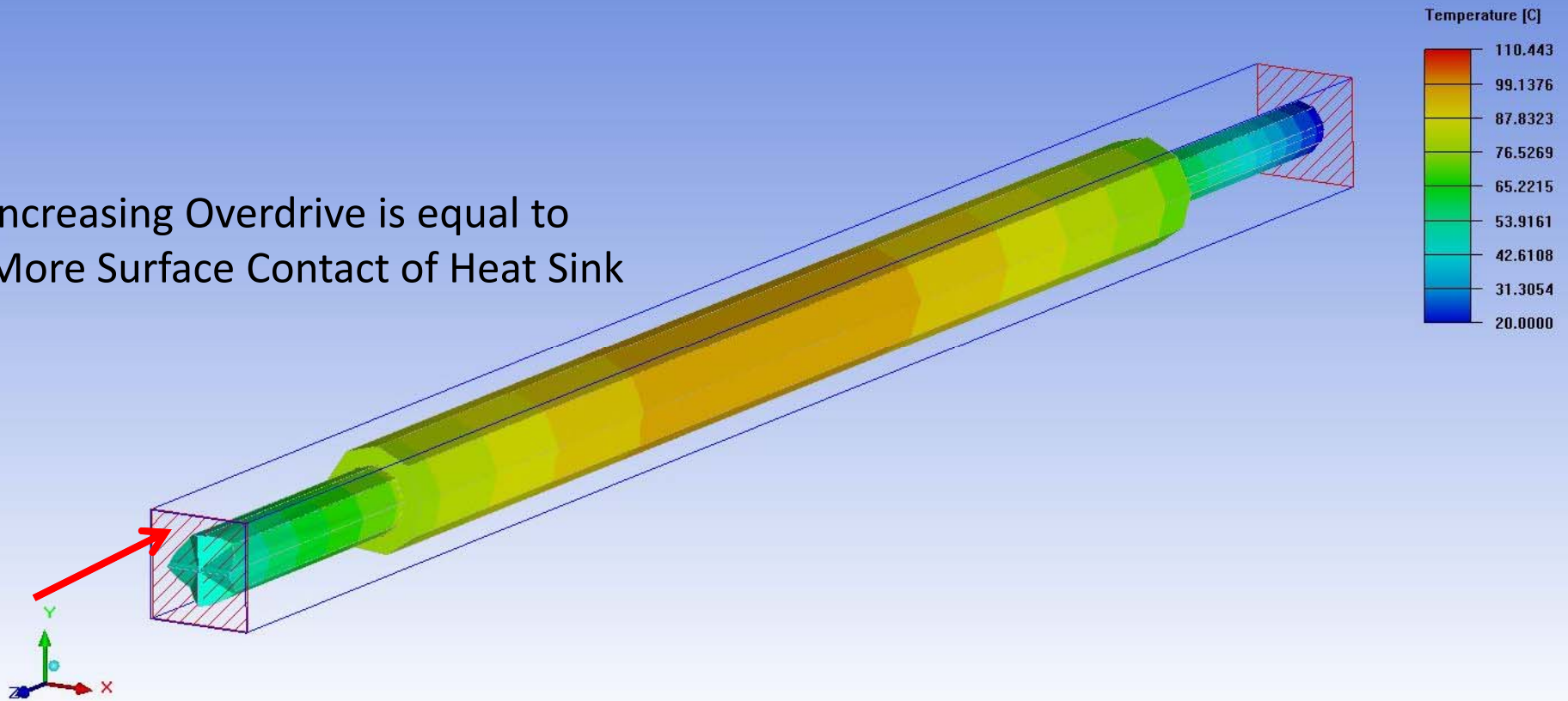
Spring Pin



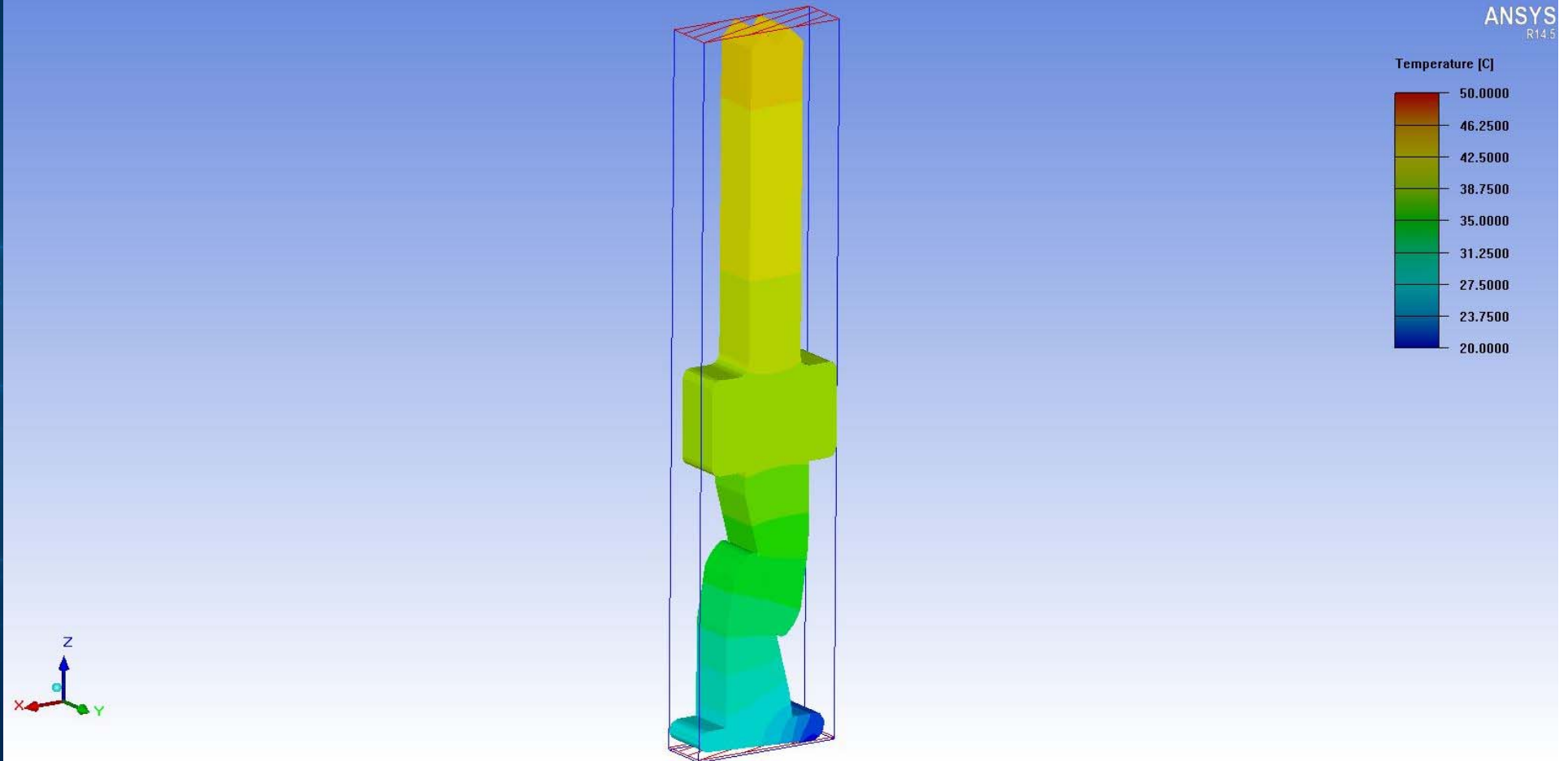
Improved Accuracy

ANSYS
R14.5

Increasing Overdrive is equal to
More Surface Contact of Heat Sink

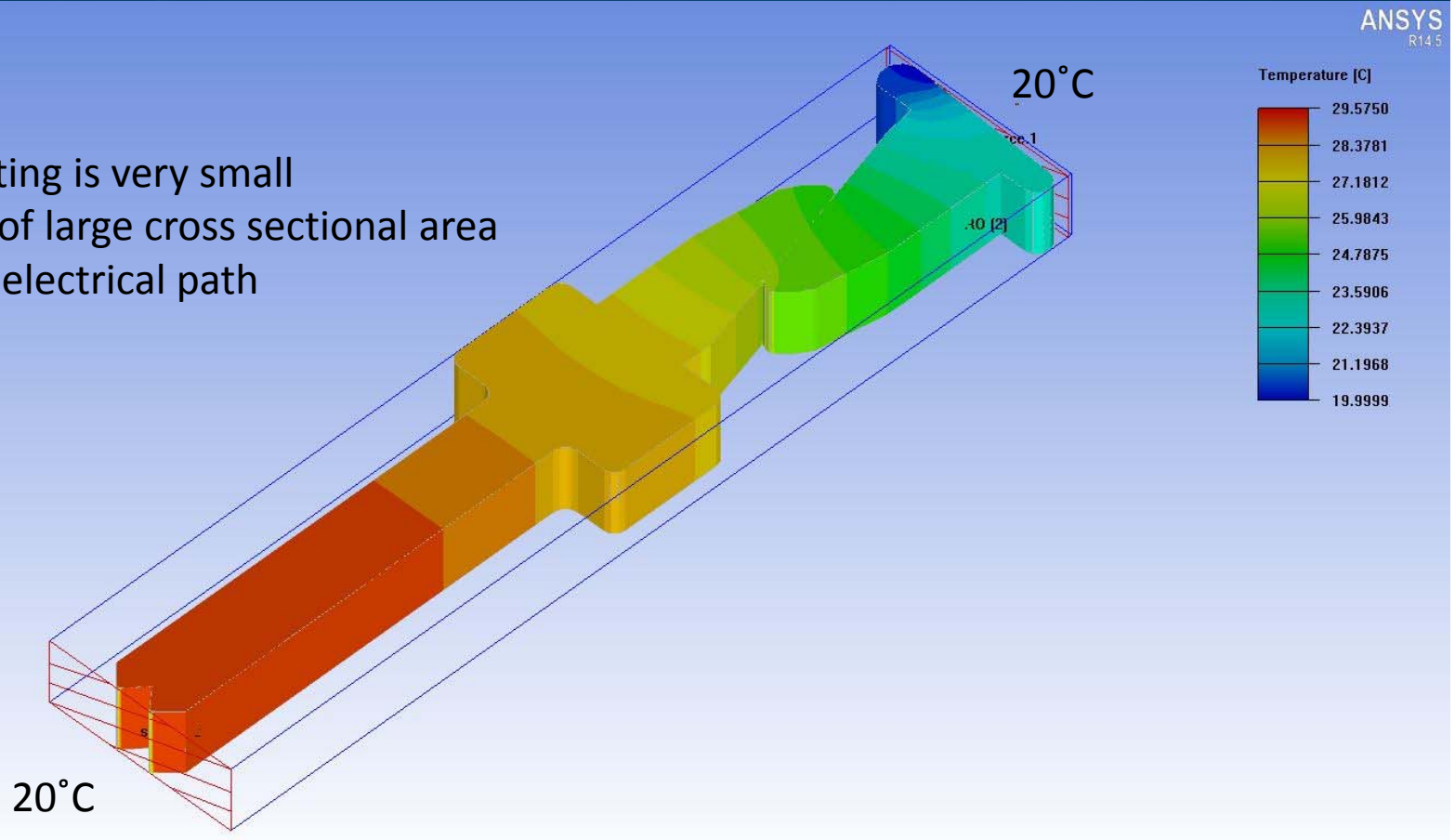


Solid Probe

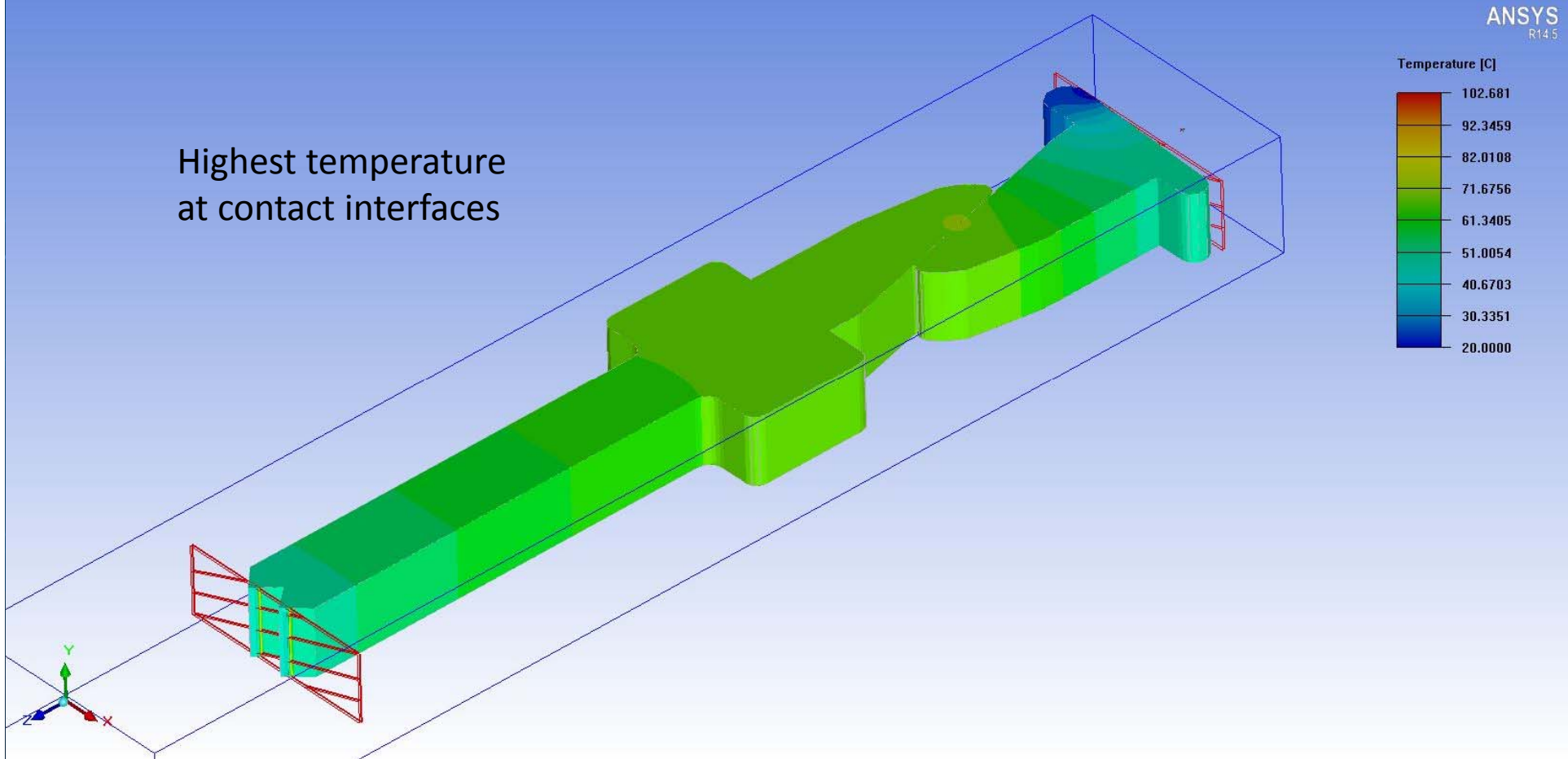


2nd Iteration

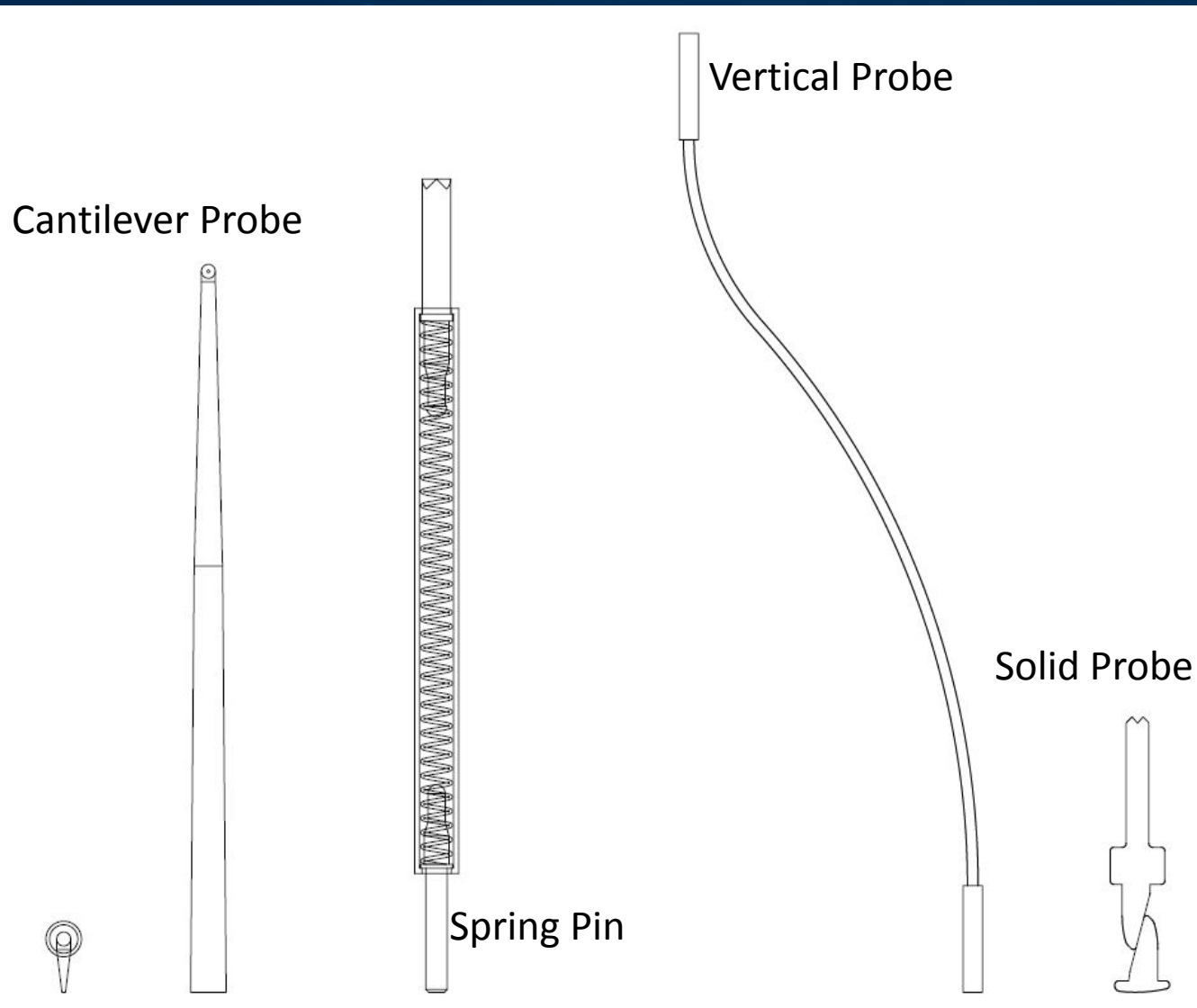
Joule Heating is very small
based off of large cross sectional area
and short electrical path



Adding Contact Resistance and Natural Convection



Probe Type Conclusions



- Vertical Probe has the longest length leading to higher temperatures
- The cantilever probe has a small cross-sectional area leading to high current density
- The Spring Pin has a contact resistance between the tips and the barrel leading to increased heating
- Solid Probe has the lowest Joule heating effect, but has internal contact resistances

Increasing Accuracy

- Adding Real Heat Sinks
 - Active DUT Heating
 - Conduction to Retaining Features
 - Natural Convection
 - Contact Resistance
 - Load Board Trace Cooling

Computational Conclusion

- Generate physical geometry for computational requirements
- Conduct accurate meshing and validate
- Review results and iterate with increasing complexity for best correlation to reality

Why Should You Care?

- Tomorrows devices will have higher transistor density and run hotter. We must address that today.
- Leveraging computational thermal analysis at the wafer scale will create better and faster designs pushing innovative solutions

Questions?

