SW Test Workshop

Semiconductor Wafer Test Workshop

Data-Driven Comparison and Qualification of WLCSP Probes

Show Me the Data

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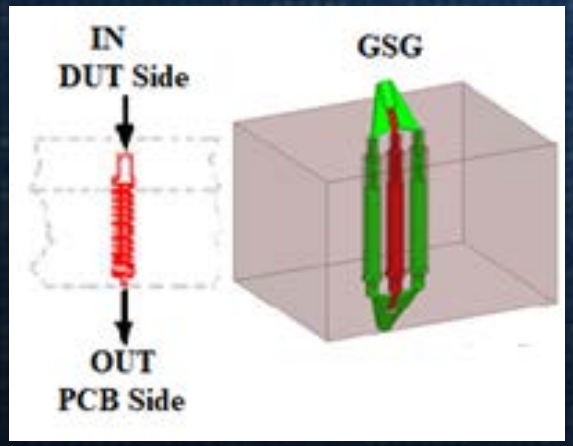
Overview

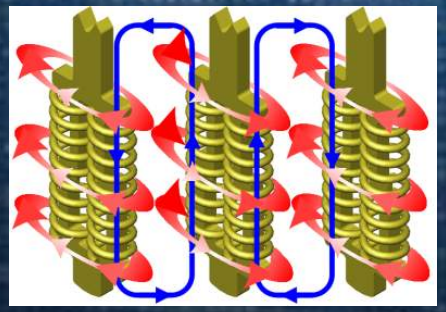
- **Key Performance Measures**
  - Electrical
    - SPICE and S Parameter Models
    - Insertion Loss and Return Loss
    - Crosstalk
    - Eye Diagrams/Patterns
    - Probe Resistance
      - Test Height/ Compliance
    - Current Rating
  - Metrology
- **Conclusion**

Making Informed Data-Driven Decisions

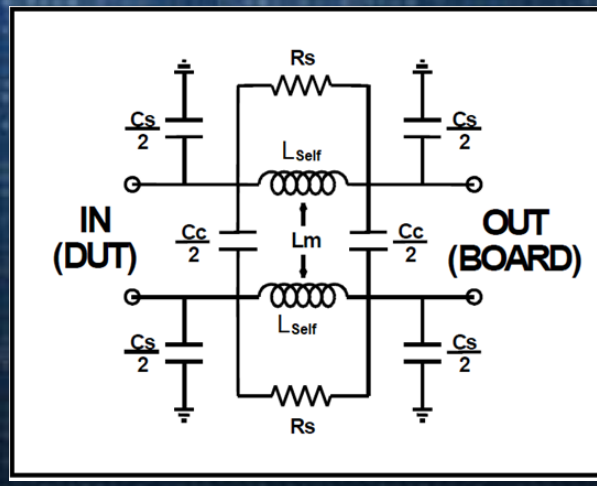
SPICE Models

1. **Most probe suppliers have equivalent circuit SPICE (Simulation Program with Integrated Circuit Emphasis) compatible models.**
2. **Inductance should be specified as loop inductance:**
   a) Loop inductance relates to the actual performance at all frequencies and all probe spacing pitches
   b) Self inductance is close to impossible to measure, and most often determined using approximations



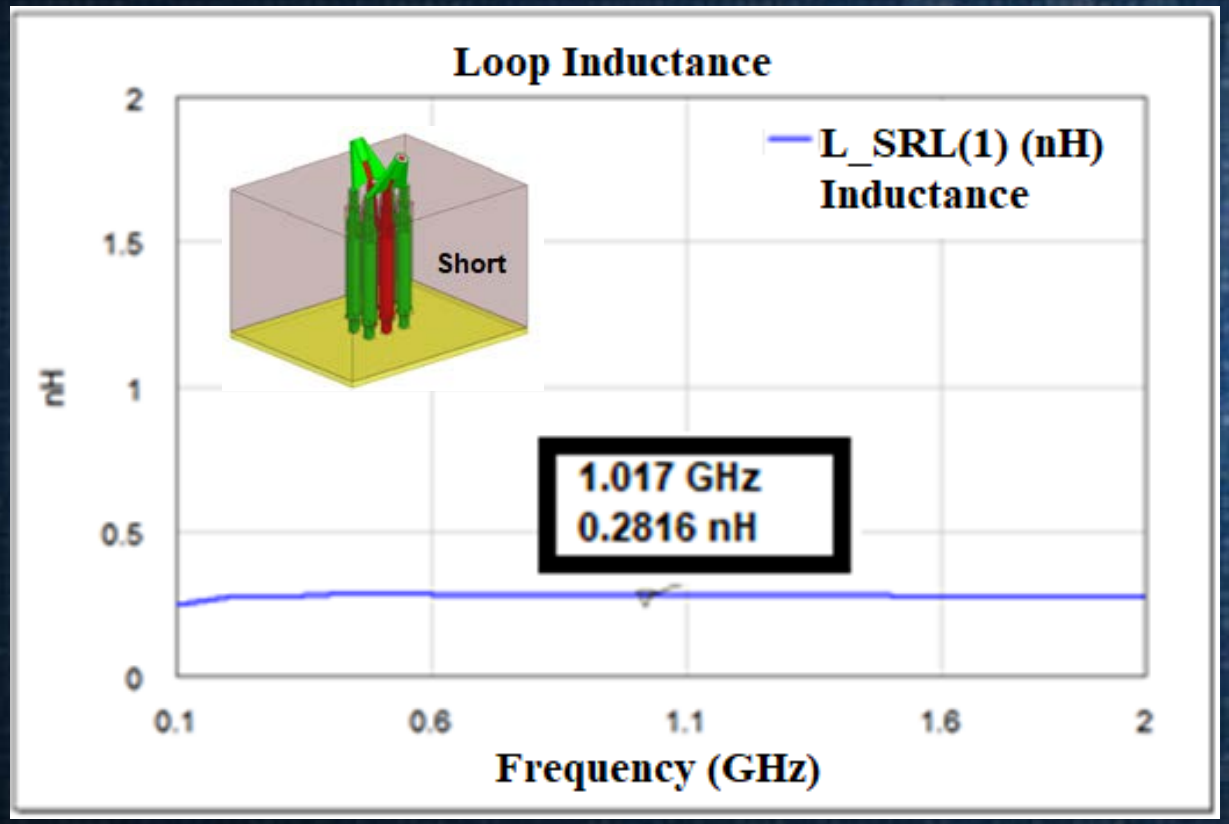


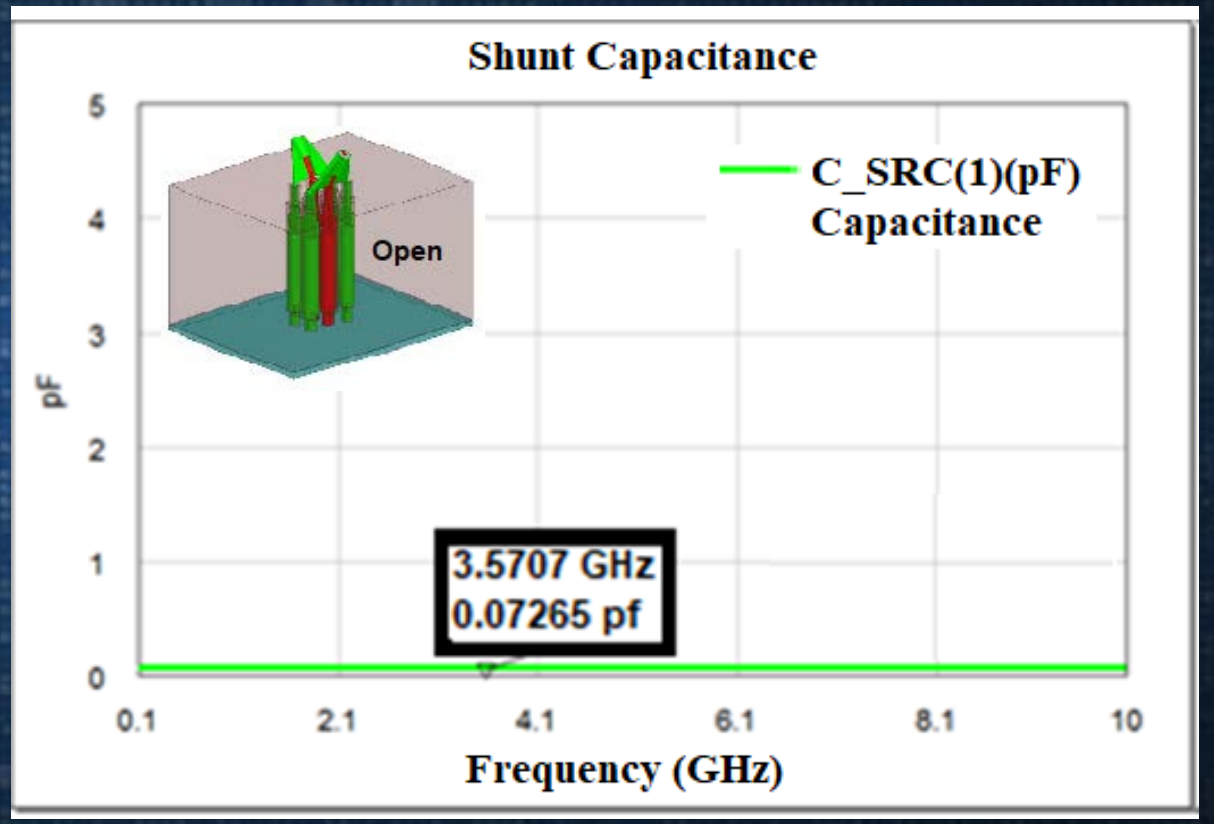
Electric Fields and Current Flow



L_{LOOP}	Loop Inductance	Measured (VNA) and Simulated (HFSS) GGS
C_{SHUNT}	Shunt Capacitance	Measured (VNA) and Simulated (HFSS) GGS
C_{MUT}	Mutual Capacitance	Simulated (HFSS) GSSG
L_{MUT}	Mutual Inductance	Simulated (HFSS) GSSG

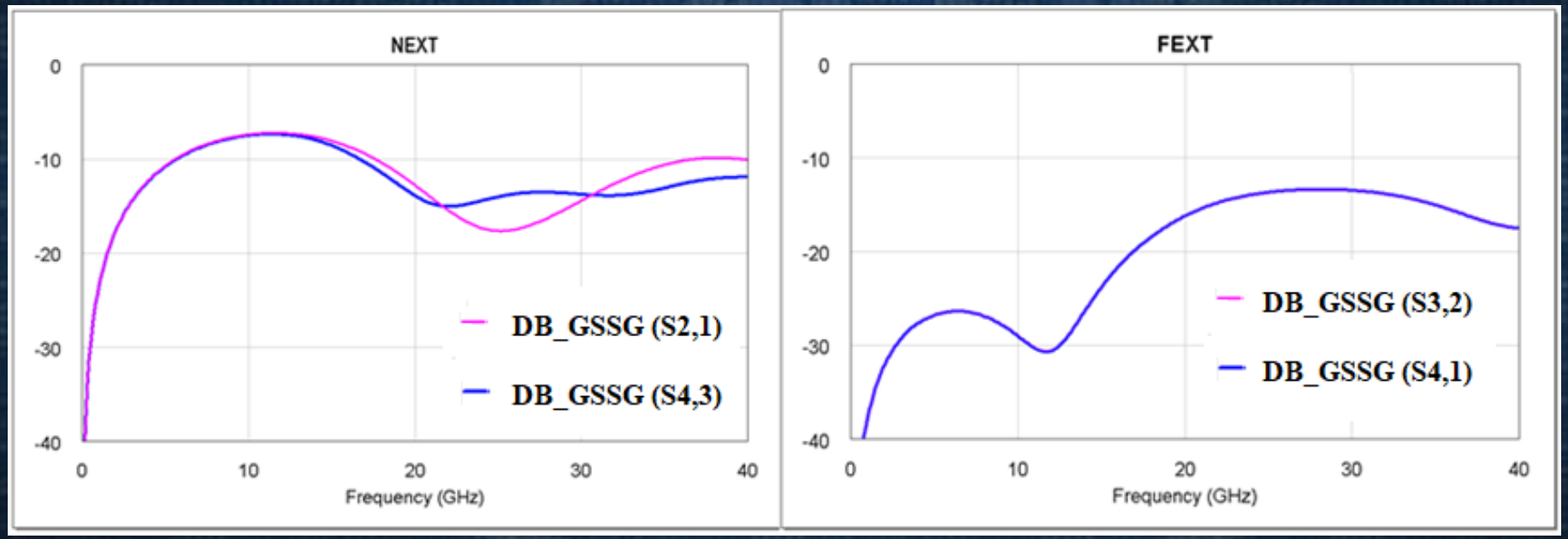
Inductance and Capacitance

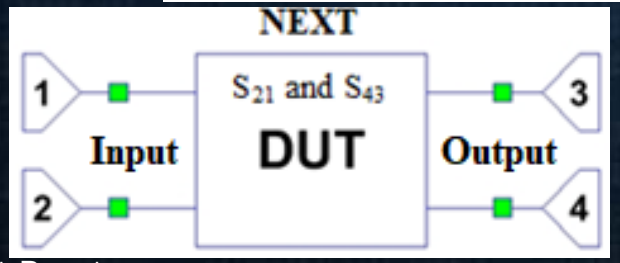




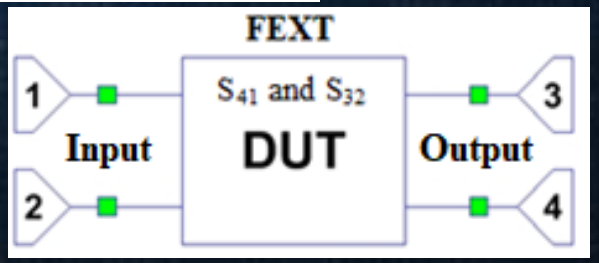
Crosstalk

- Near-End Crosstalk is the crosstalk measured from the input of one signal pin to the input of the adjacent signal pin. It is determined from S2,1 and S4,3 as shown on this slide
- Far-End Crosstalk is the crosstalk measured from the input of one signal pin to the output of the adjacent signal pin. It is determined from S4,1 and S3,2 as shown on this slide
- Crosstalk results shown are determined through 3D Electromagnetic simulation

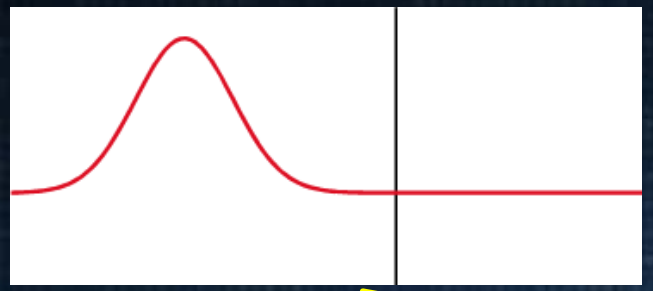




Crosstalk (dB)	Power Ratio	NEXT	FEXT
-20 dB	0.01	1.5 GHz	16.9 GHz
-10 dB	0.1	5.6 GHz	>40 GHz

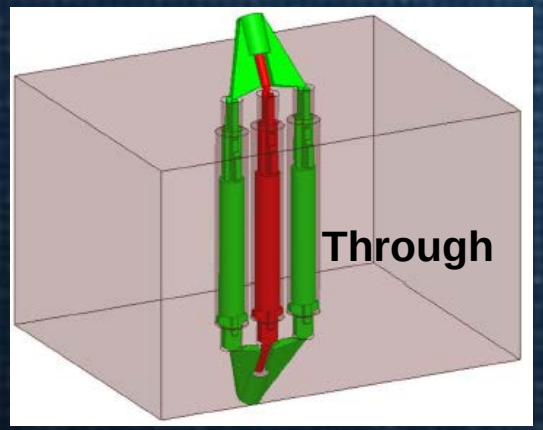


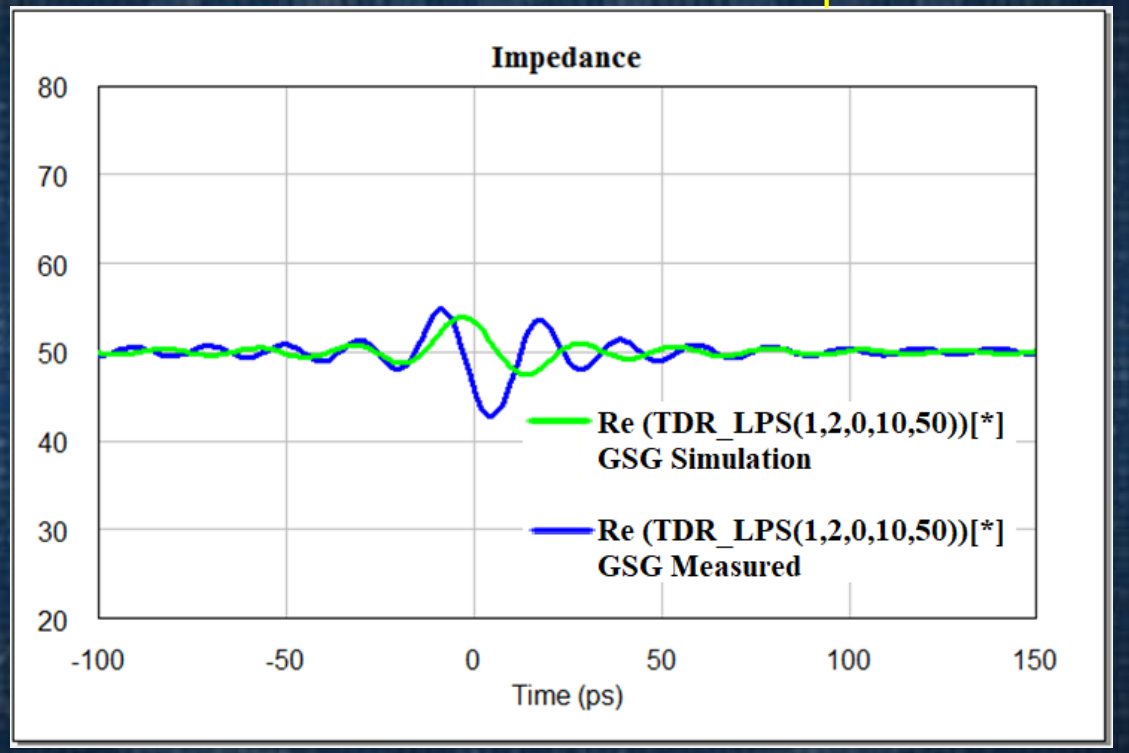
Impedance

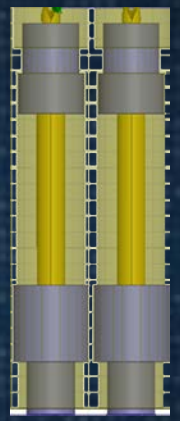


Impedance matching is the practice of designing the path to match the impedance of the signal source and destination. This maximizes power transfer and minimizes reflections

Interconnect Impedance Discontinuity







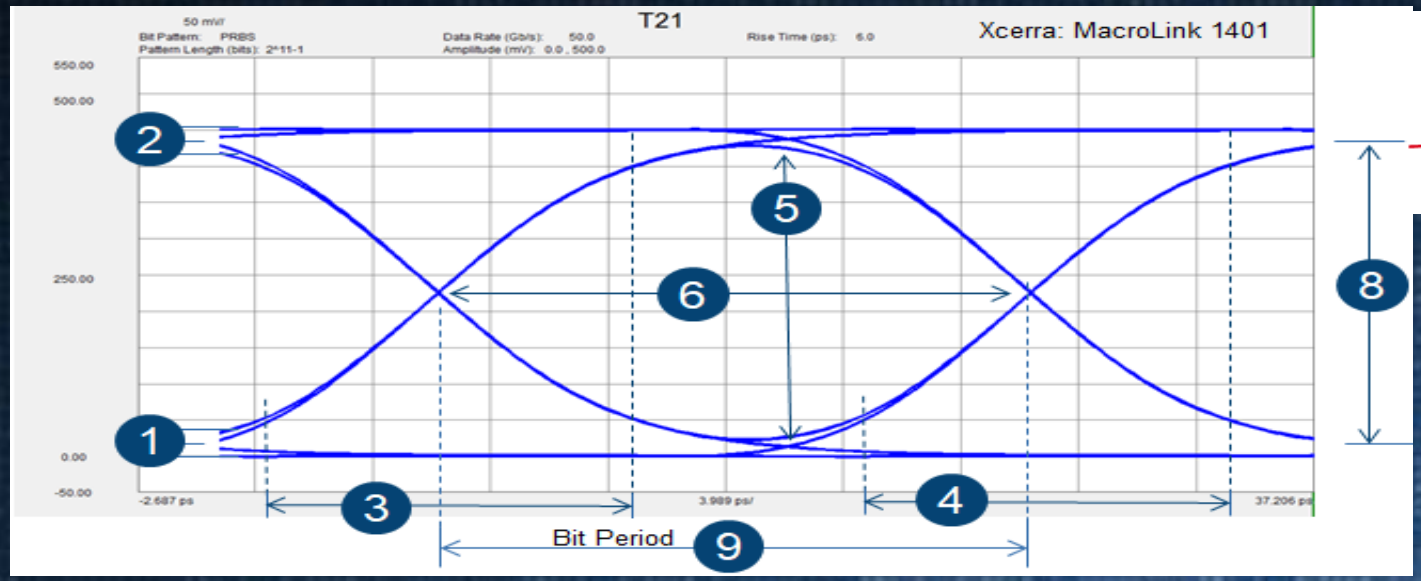
Impedance Controlled Interconnect: Coaxial Solution

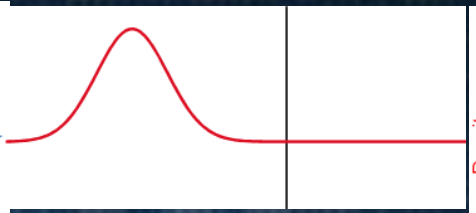
All of These Resist Current

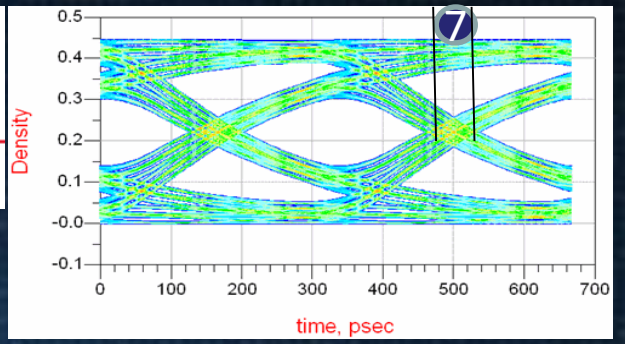
$$Z = \sqrt{R^2 + (X_L + X_C)^2}$$

Circuit Impedance Z

Eye Diagrams / Patterns





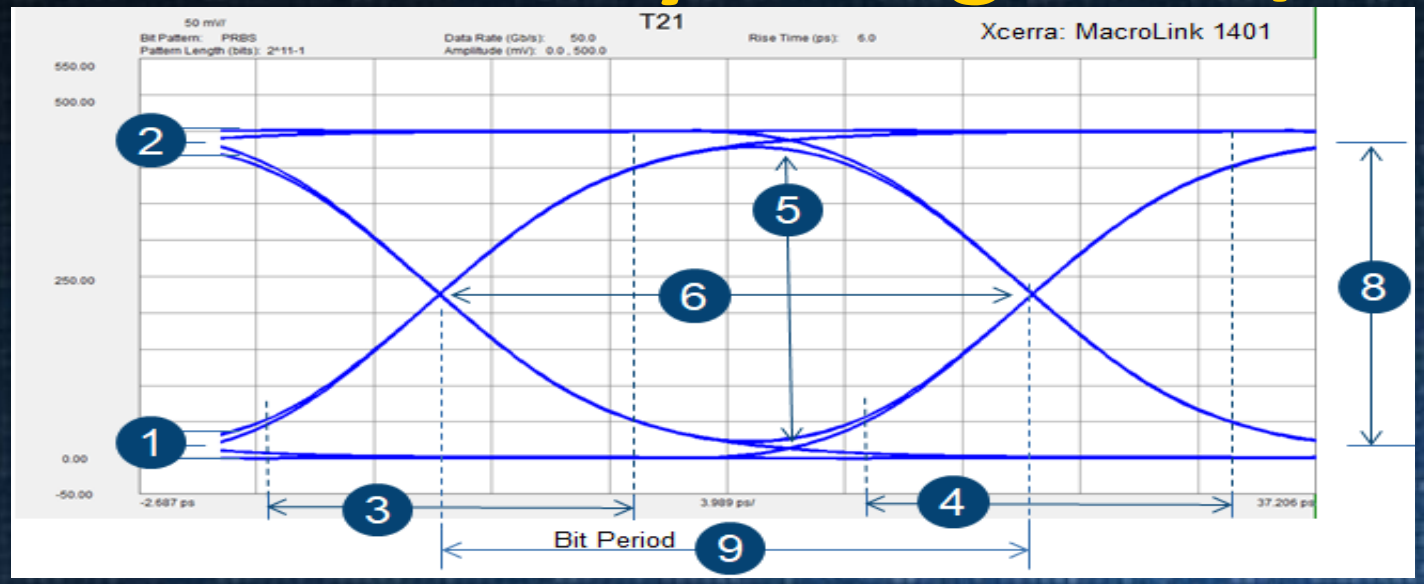


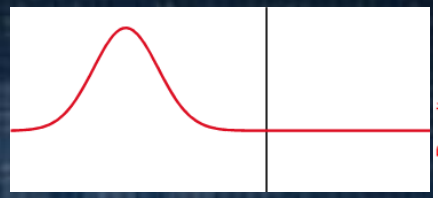
5 Vertical Eye Closure

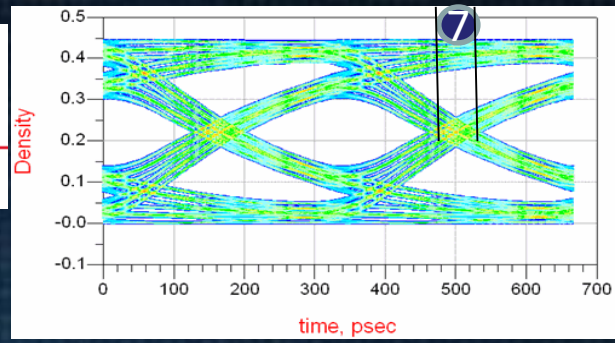
- Ground bounce, Overshoot, Reflection(bad termination)

1. Zero Level: The measure of the mean value of the logical 0 of an eye diagram. *Voltage amplitude variations*
2. One Level: The measure of the mean value of the logical 1 of an eye diagram. *Voltage amplitude variations*
3. Rise Time: The measure of the transition time of the data from the 10% level to the 90% level on the upward slope of an eye diagram.
4. Fall Time: The measure of the transition time of the data from the 90% level to the 10% level on the downward slope of an eye diagram.
5. Eye Height: The measure of the vertical opening of an eye diagram.

Eye Diagrams / Patterns



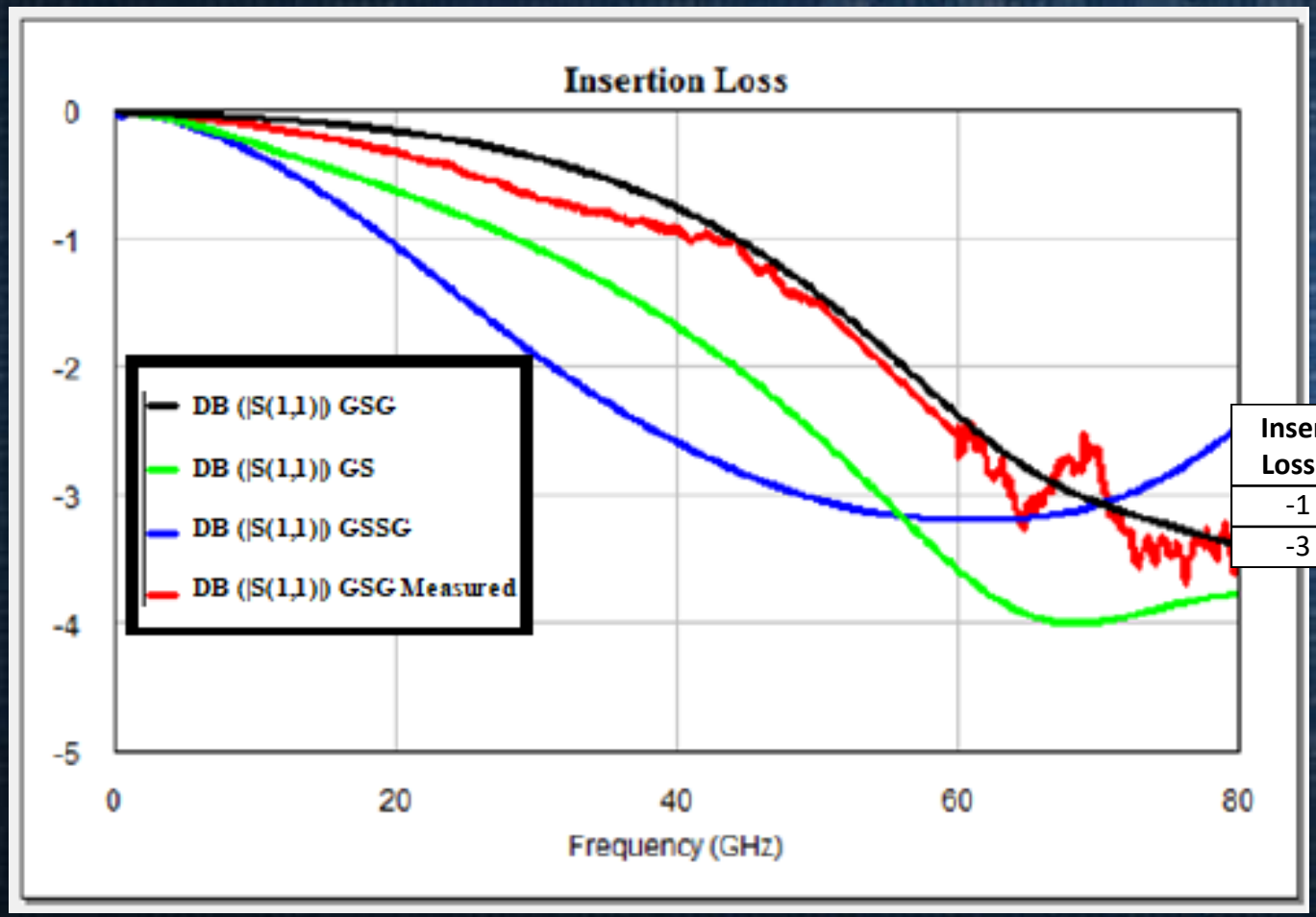


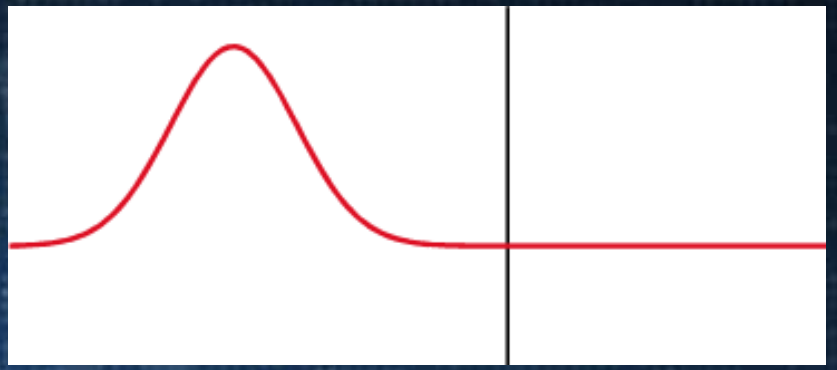


6 Horizontal Eye Closure
- Deterministic Jitter: crosstalk, impedance mismatch, i.e., things in the circuit

6. Eye Width: is a measure of the horizontal opening of an eye diagram.
7. Deterministic Jitter: is the deviation of a transition from its ideal time caused by reflections relative to other transitions. *How far is my edge from the ideal.*
8. Eye Amplitude: is the difference between the logic 1 level and the logic 0 level histogram mean values of an eye diagram
9. Bit Rate: is the inverse of bit period (1 / bit period). The bit period is a measure of the horizontal opening of an eye diagram at the crossing points of the eye

Insertion Loss



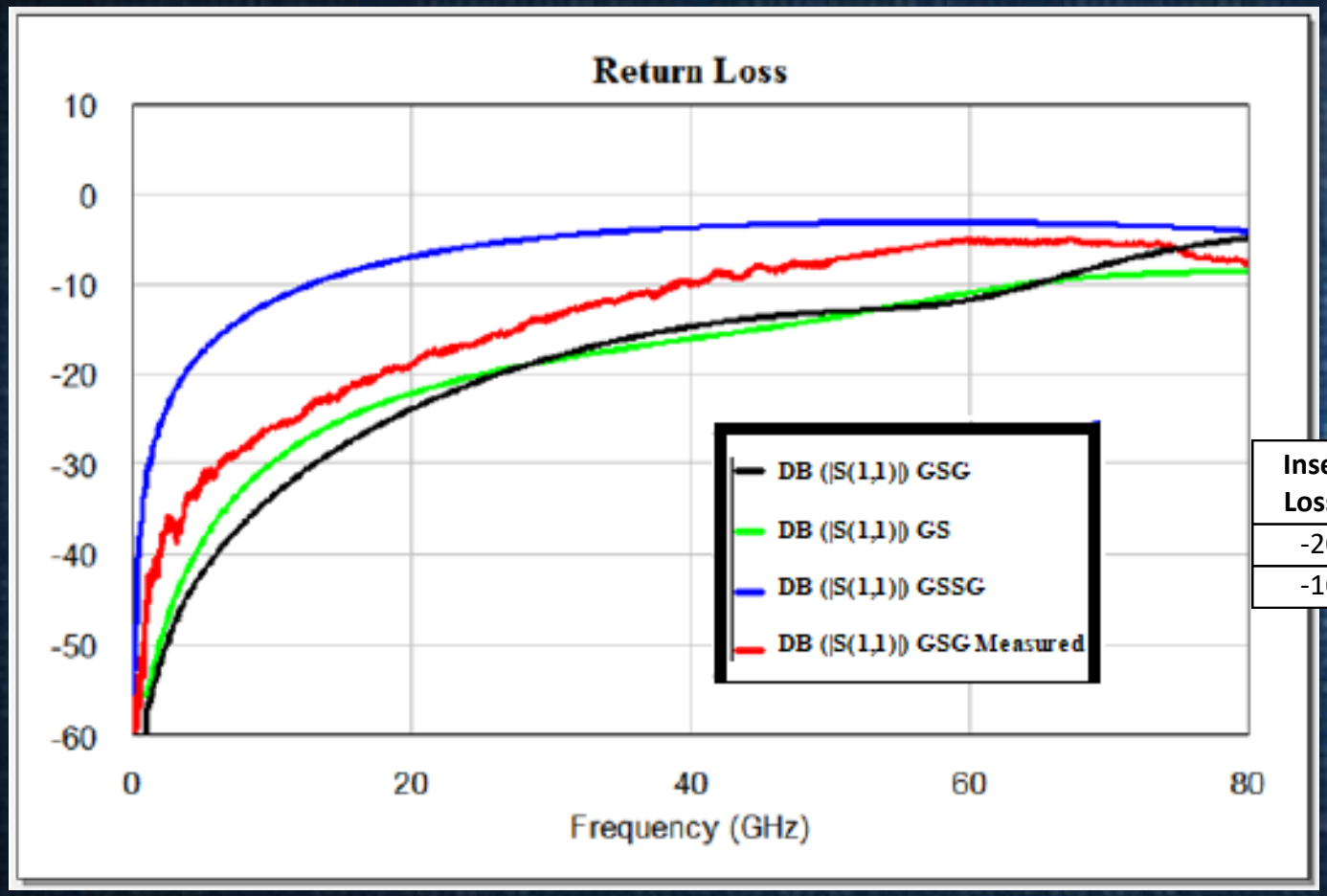


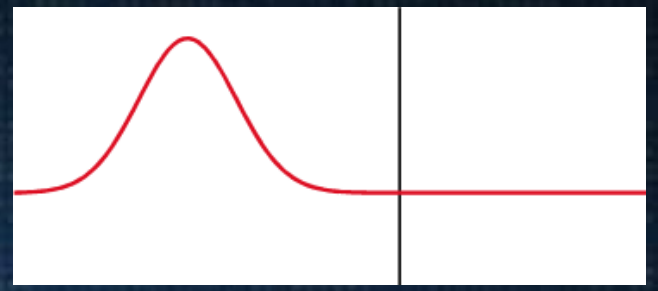
Insertion Loss (dB)	Power Ratio	Single Ended G-S	Single Ended G-S-G	Differential G-S-S-G
-1 dB	0.794	28.6 GHz	42 GHz	19.4 GHz
-3 dB	0.501≅ 1/2	54.5 GHz	64 GHz	49 GHz

Insertion loss is the:

- Ratio of Power Out to Power In
- P_{out}/P_{in} = Power Ratio
- IL=log10 (P_{out}/P_{in})= xdB

Return Loss



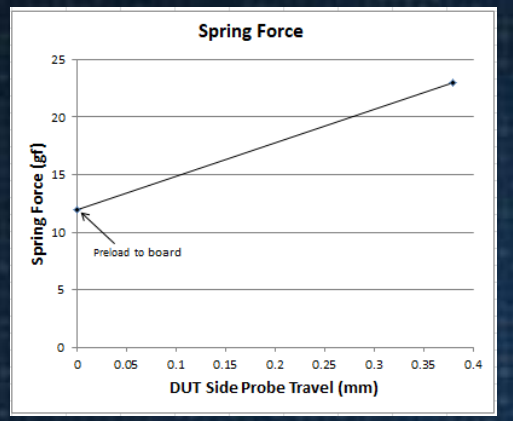


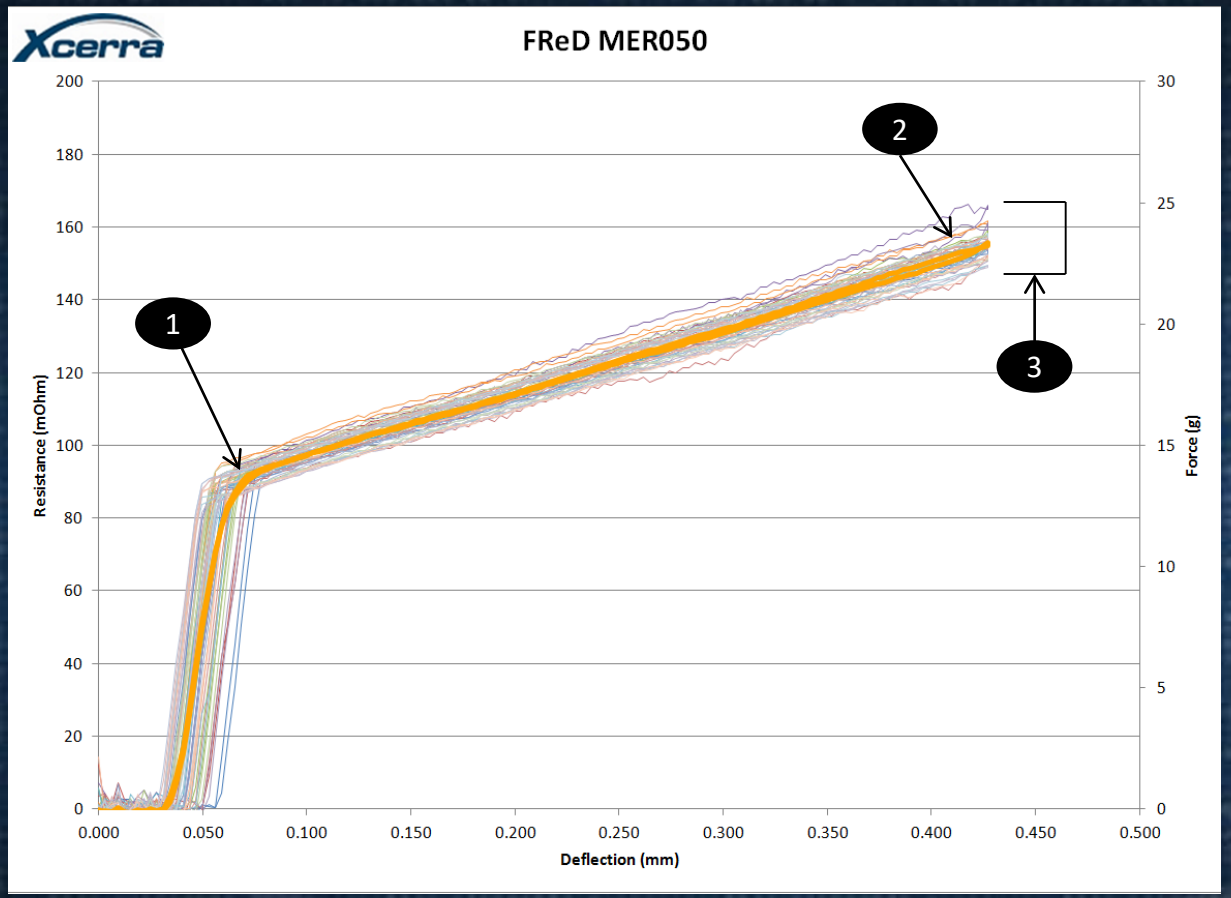
Insertion Loss (dB)	Power Ratio	Single Ended G-S	Single Ended G-S-G	Differential G-S-S-G
-20 dB	0.01	24.8 GHz	17.8 GHz	3.7 GHz
-10 dB	0.1	64 GHz	38.6 GHz	12.3 GHz

Return loss is the:

- Ratio of Power Returned to Power In
- $P_{returned} / P_{in} =$ Power Ratio
- $RL = \log10 (P_{return} / P_{in}$

Probe/Spring Force



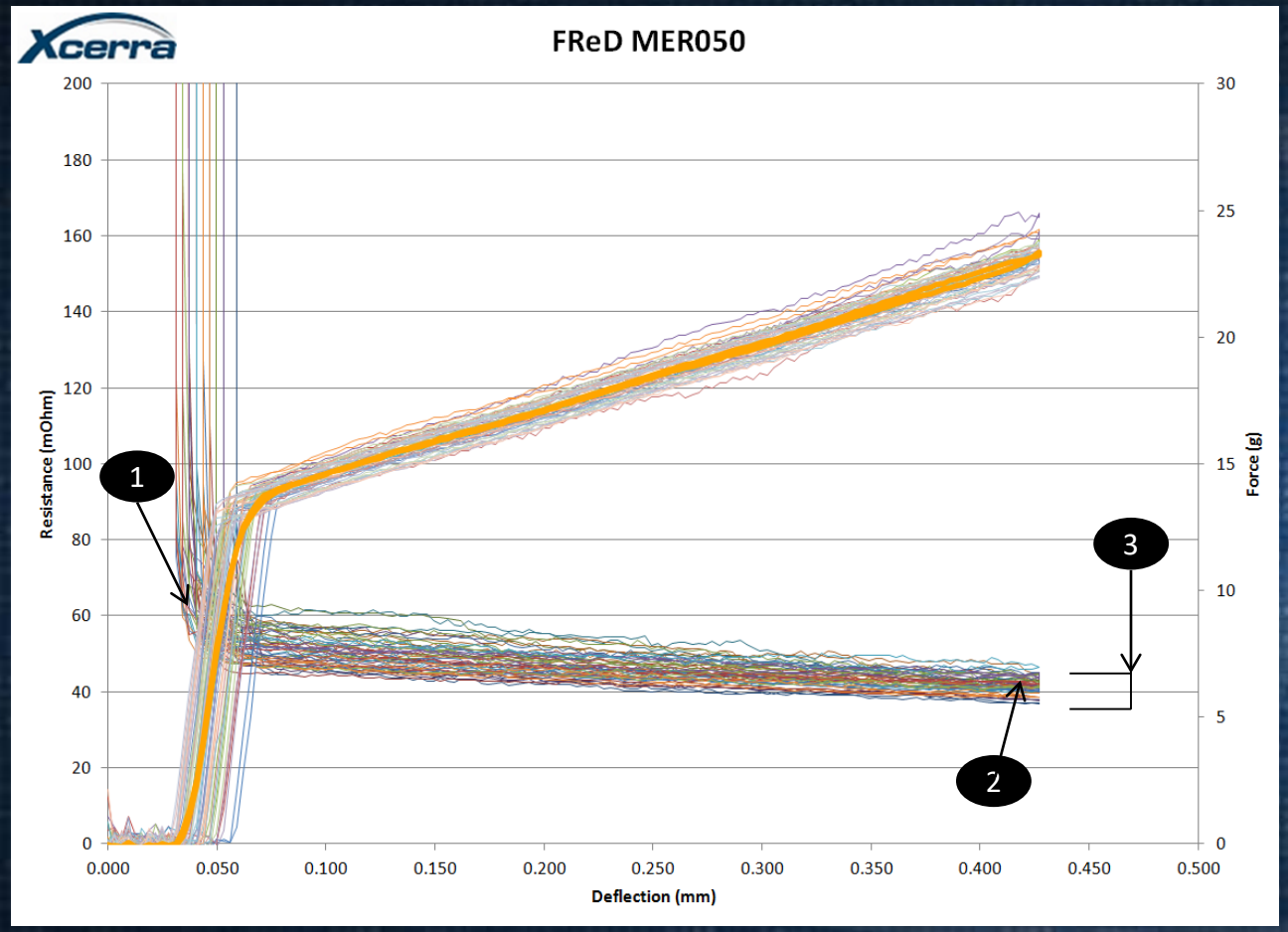


- **F**orce
- **R**esistance
- e
- **D**eflection

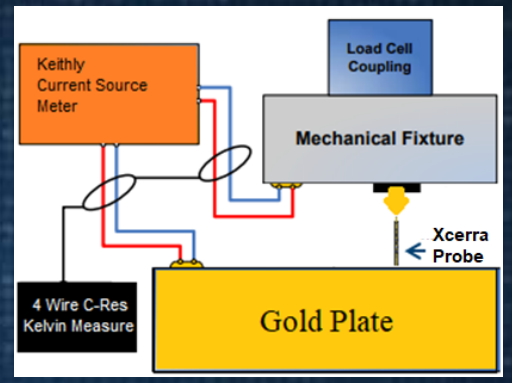
1. Force at Preload
2. Force at Test Height
3. Distribution of Force at Test Height

Force Plot (FReD)
Development of the FReD plot includes the random selection of a number of probes that are mounted in a fixture and then compressed to test height. The result is a systematic measure of the probes performance in the force domain. The sample size is determined to statistically represent a population

Spring force and Probe Resistance



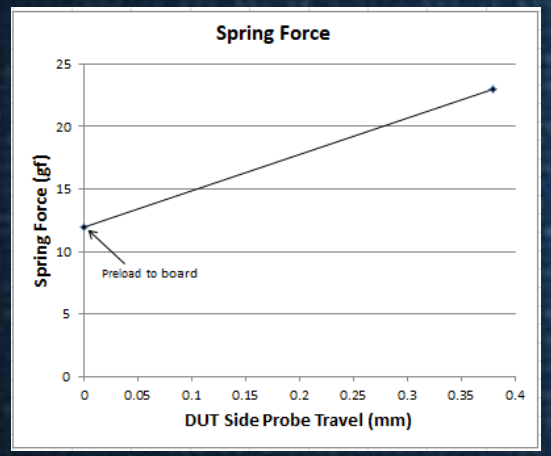
1. Probe Resistance at First Point of Contact
2. Probe Resistance at Test Height
3. Distribution of Probe Resistance

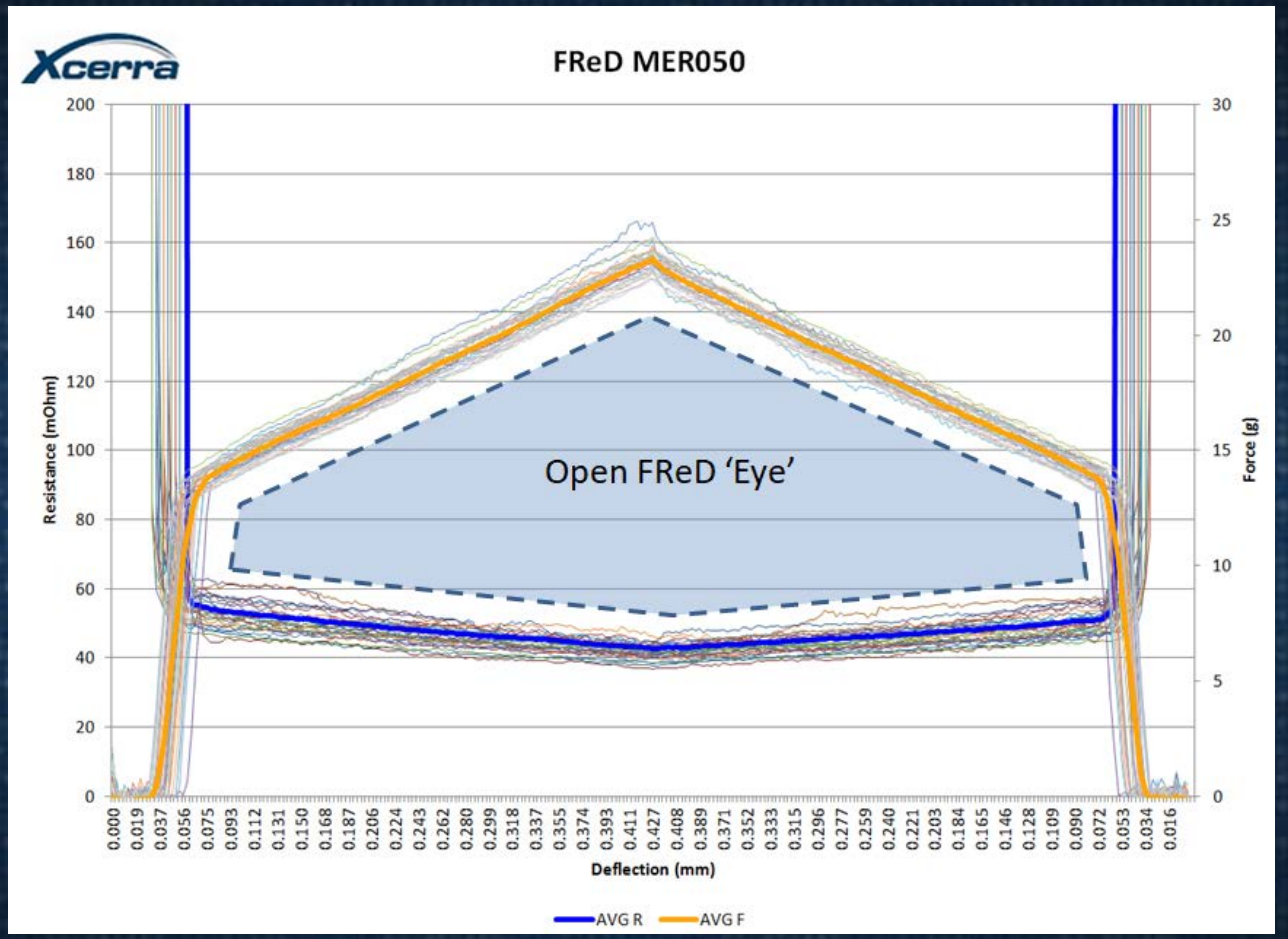


- **F**orce
- **R**esistance
- e
- **D**eflection

The FReD setup allows for measurement of probe resistance during probe compression. This process emulates the resistance of the probe as it contacts a Device-Under-Test.

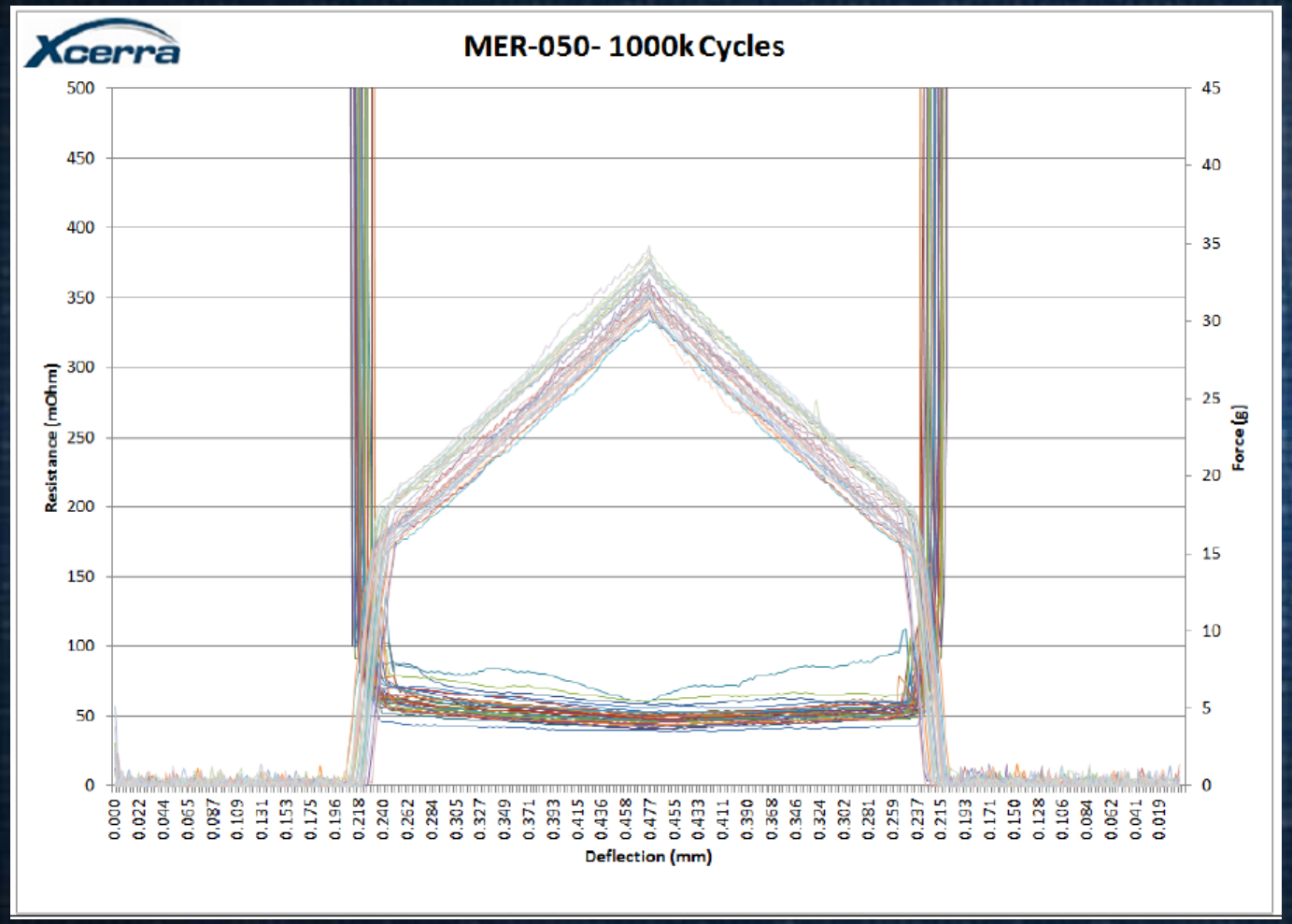
Force-Resistance and Deflection

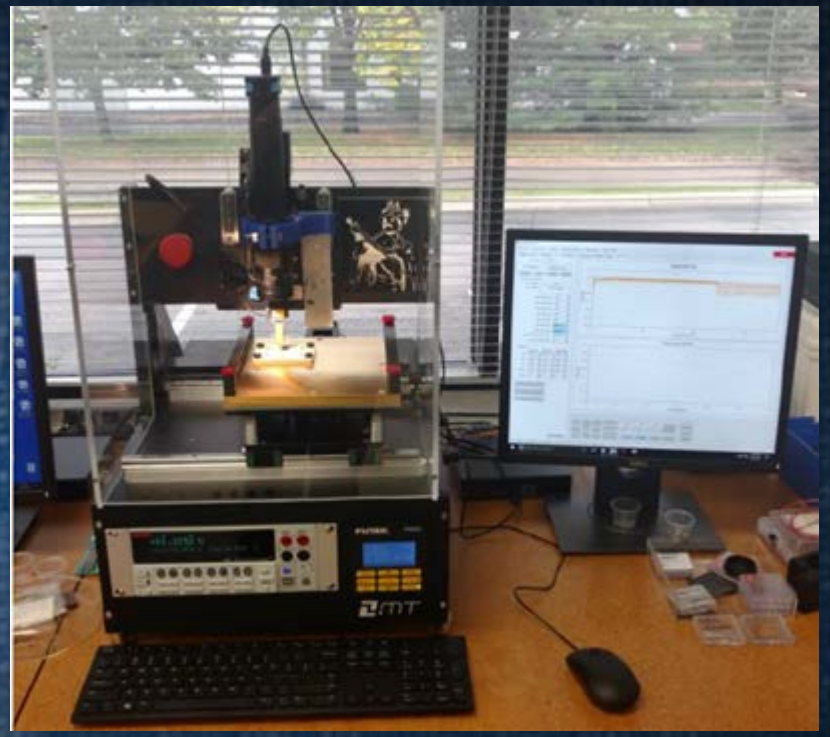




- **F**orce
- **R**esistance
- e
- **D**eflection

Force Resistance Life Cycle Testing

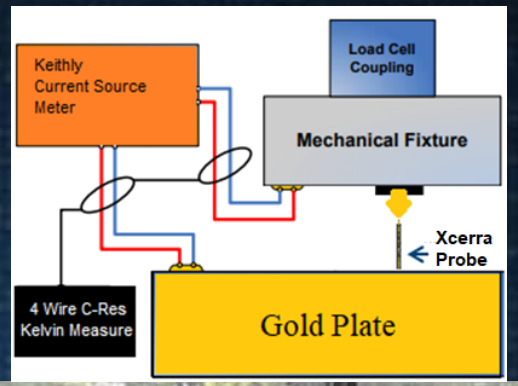


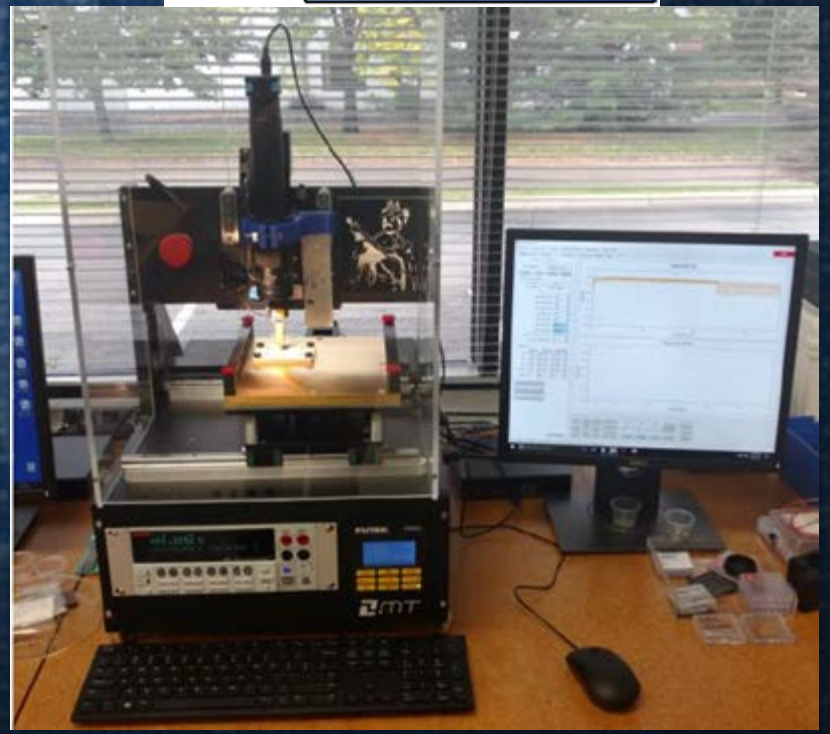


It is good to know the statistical resistance of a probe throughout it's projected life!

Current Carrying Capability Measurement

- ISMI force reduction method for developing a current rating

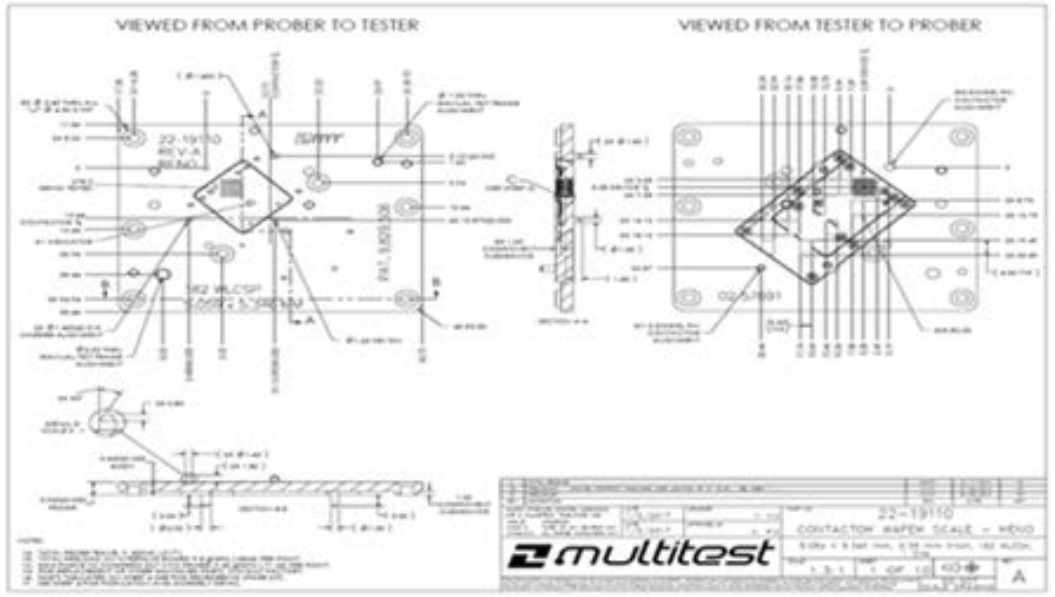




Metrology Cover Sheet and Pass Fail Report

MT Assembly Number: 22-19110
Serial Number:
Inspection Date:
Probe Used: 07-1063 MER-030-DJ-Au
Tester: MTMN FReD 7
Tested by: MBB

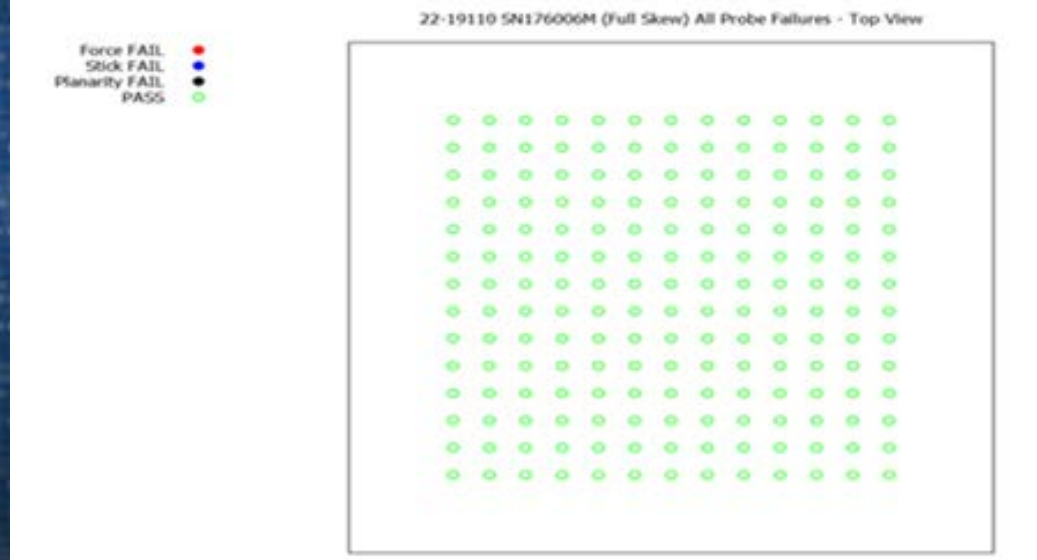
Probe Head Drawing (First Page Only)



MT Assembly Number: 22-19110
Serial Number:
Inspection Date:
Probe Used: 07-1063 MER-030-DJ-Au
Tester: MTMN FReD 7
Tested by: MBB

Probe Head Planarity/Force/Sticking

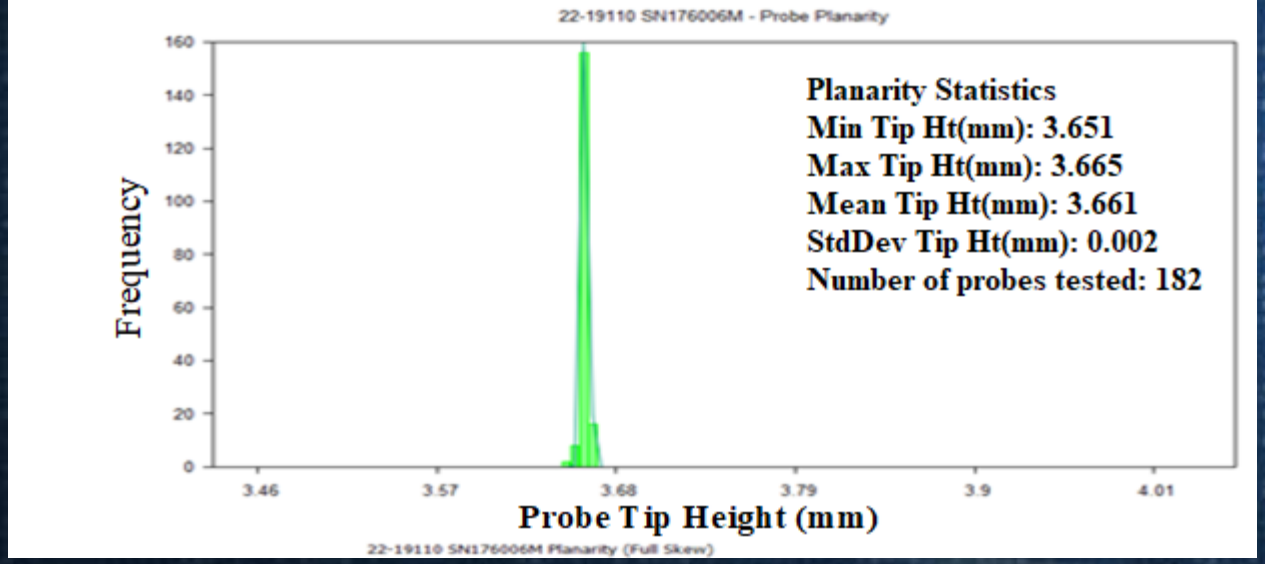
Force Range – Min: 10g
Max: 26g
Min Tip Height: 3.60 mm

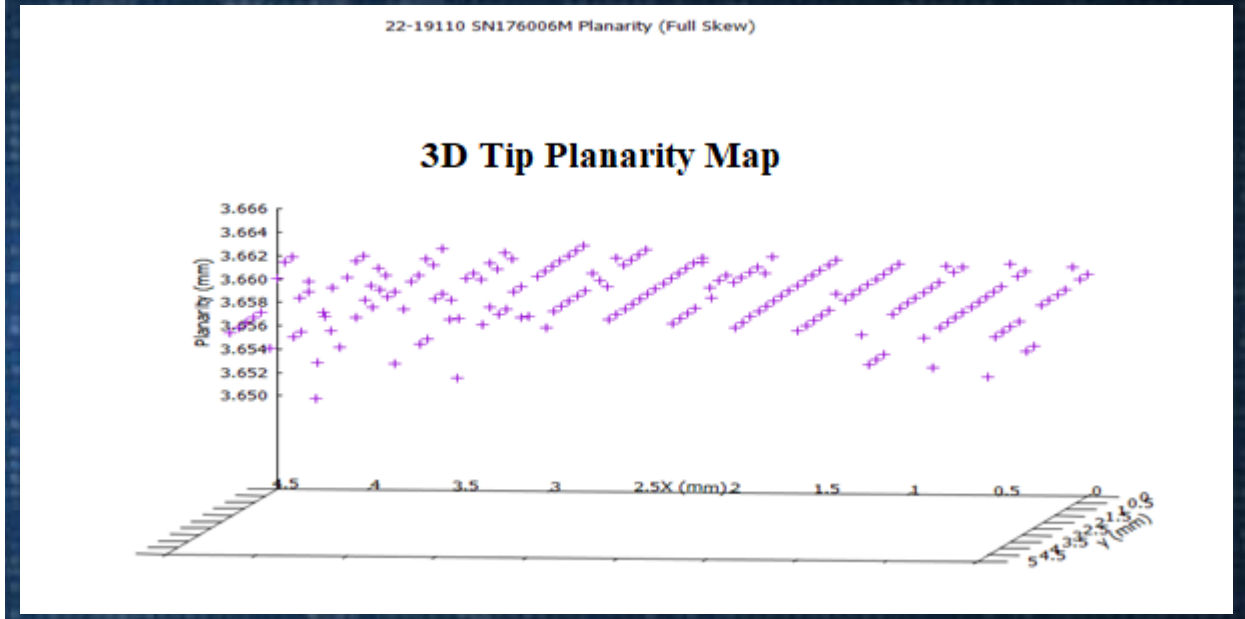


Metrology Report Probe Planarity

MT Assembly Number: 22-19110
Serial Number: SN176006M
Inspection Date:
Probe Used: 07-1063 MER-030-DJ-Au
Tester: MTMN FReD 7
Tested by: MBB

Probe Head Planarity

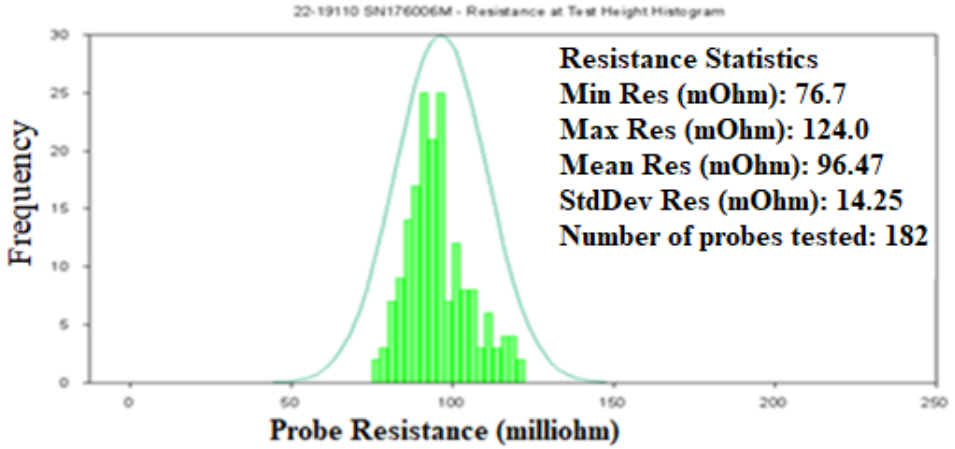


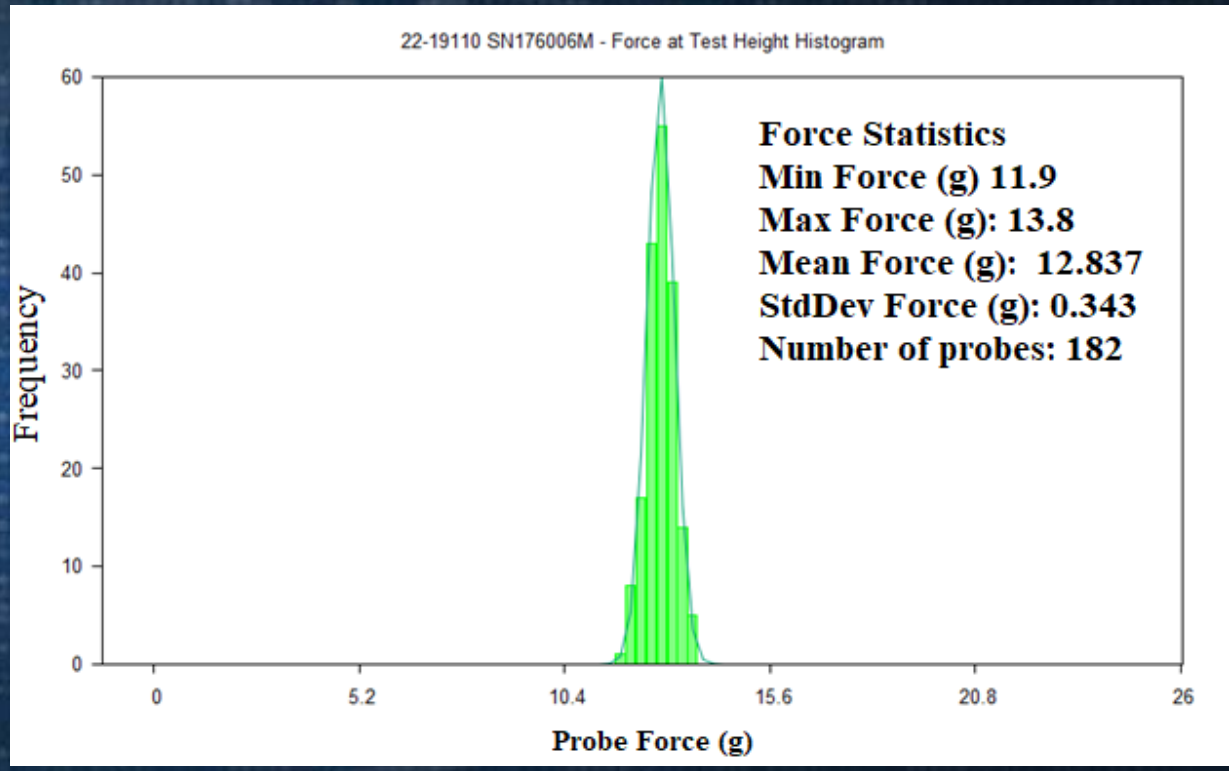


Metrology Report
Probe Resistance and Force at Test Height

Serial Number: SN176006M
Inspection Date:
Probe Used:
Tester: MTMN FReD 7
Tested by: MBB

Probe Resistance





Conclusion

- Not all specification are created equal
- Know and understand how the numbers that specify a probe head and/or probe card were developed.

- Don’t be afraid to say “**Show Me the Data**!”

Contributing Team Members

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Jason Mroczkowski
Marty Cavegn
Nadia Steckler
Valts Treibergs

Thank You for Attending and Listening

Questions Please