Optimal Spring Probe Solutions for Every Application

Valts Treibergs
Johnstech International

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Agenda

- Background
- Testing Application Challenges – Overview
- Electrical Challenges
  - Existing predominant solutions available
- Next Generation HF testing solution using the HF Spring Probe family
  - Internal electrical and mechanical qualification
  - RF Applications and field performance
- Mechanically challenging applications
  - Introduction to the robust ‘bread and butter’ HC solution

Application Challenge – Electrical or Mechanical? (or both?)

- Electrical challenges:
  - High data rate – digital
  - High frequency
  - High power
- Mechanical challenges
  - Large package(s) – planarity
  - Multi-site testing
  - Overcome large stack-up tolerances
  - Old handlers & kits – very loose tolerances – imprecise DUT presentation
  - Thermal control

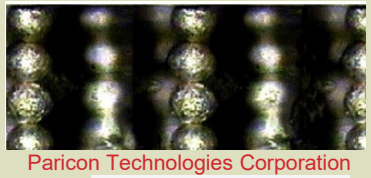
- PAM-4
- 5/6 G
- RADAR
- Amplifiers
- Filters

- Low Inductance
- Matched Impedance
- Low Insertion Loss
- Low Return Loss

- Big BGA modules
- Package warp
- Worn out kits
- Strip test

Electrical Challenges & Existing Solutions

- Maximize data rate or frequency response – how?
  1. Low inductance with short test height
  2. Matched impedance to the test environment
- Z-axis Conductive Elastomers
  - Very short signal path:
    - Low inductance
    - Good S_{11}, S_{22}
- Coaxial or coplanar waveguide
  - Good impedance match
  - Good isolation
- Short spring probes
  - Low inductance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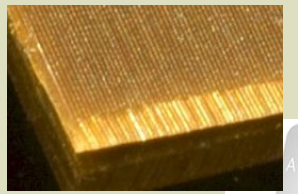
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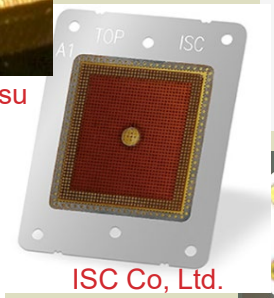
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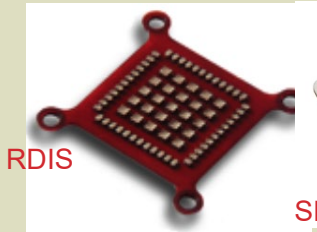
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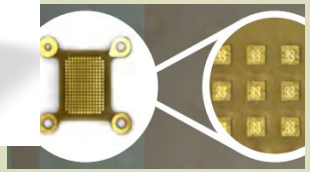
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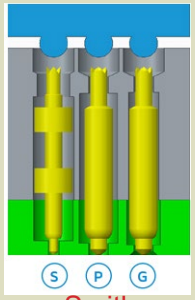

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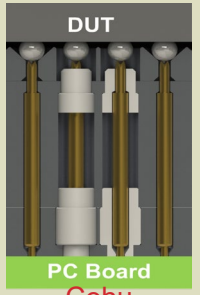

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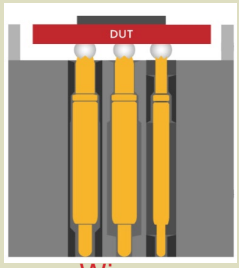
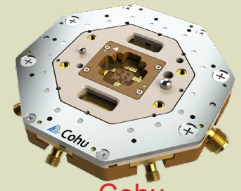


Winway



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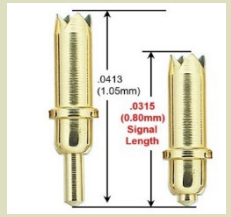

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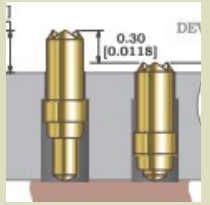
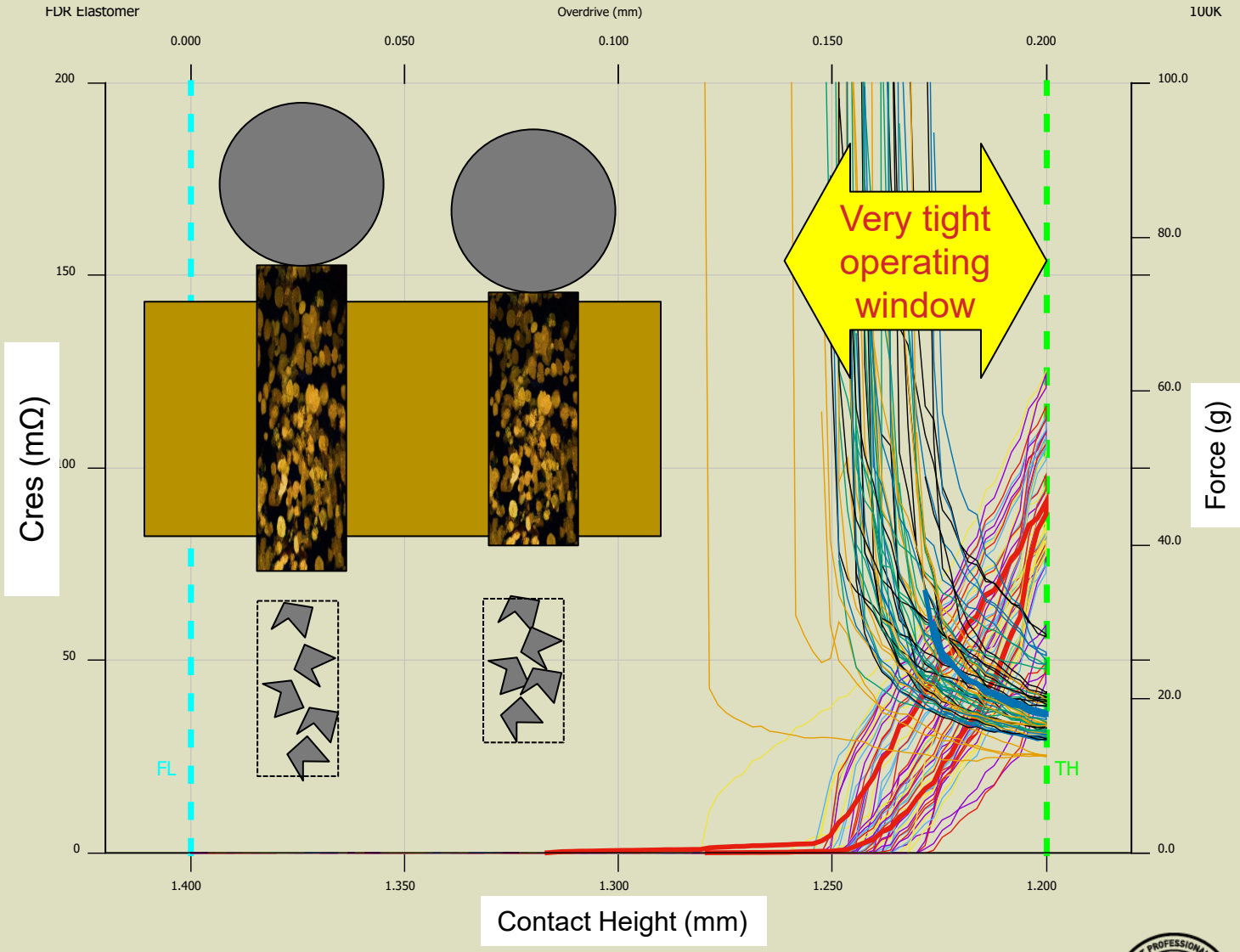


Kita Manufacturing

TestConX™

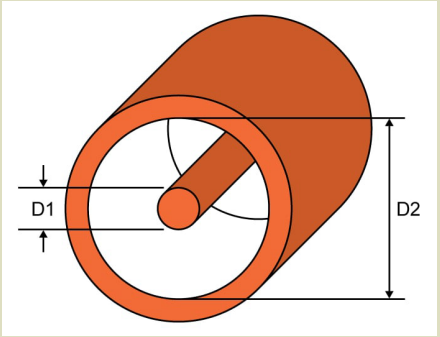
Electrical Challenges – Elastomer Solutions & Limitations

- Benefits:
  - Very short signal path (low inductance)
- Problems:
  - Less compliance
  - Performance at hot/cold temperatures
  - High force to DUT – possible damage
  - Variable contact resistance – conductive particle contact variability
  - No preload to PCB



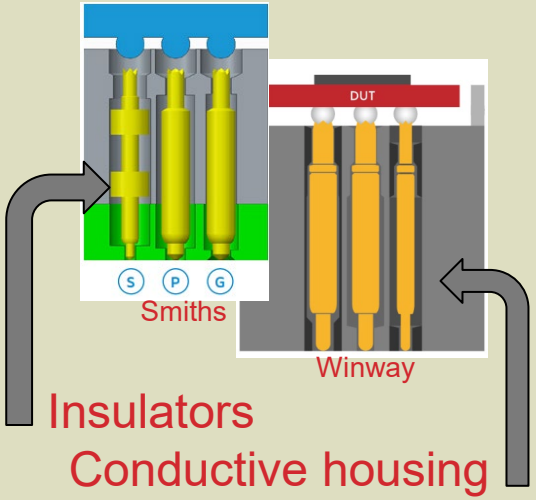
Electrical Challenges – Impedance Controlled Solutions & Limitations

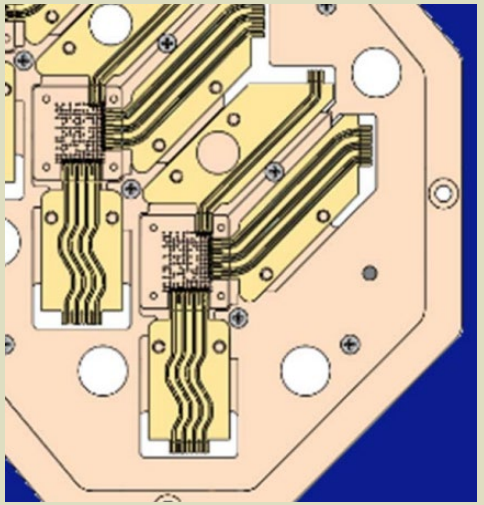
- Coaxial
  - Complex structure – maintenance - insulators
  - Center signal conductors – very small for DUT pitch – low force/high Cres/low CCC
- Coplanar Structures
  - Accessible to outer perimeter of DUT only
  - Required mixed technologies (spring probes, etc.)



$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \ln \frac{D_2}{D_1}$$

50Ω Example
DUT Pitch: 0.5mm
D2=0.45mm
ϵ_r=2.1 (Teflon)
D1=0.134mm



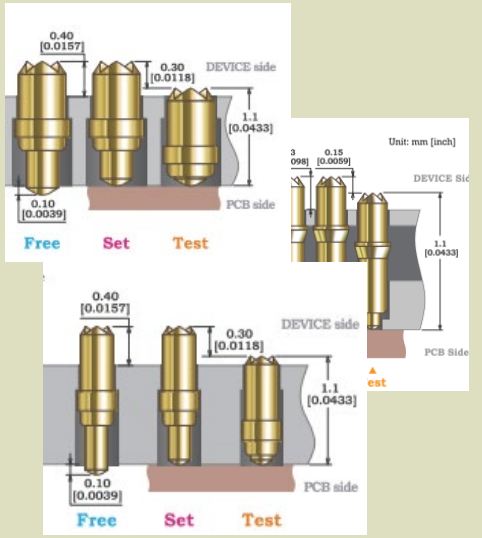


Production Wafer Probe of 77-81 GHz Automotive Radar Applications

Electrical Challenges – Short Spring Probe Solutions & Limitations

- Available from quite many suppliers
- All of different designs and test heights
- Limited pitch variations from any given supplier
- Spring material – may limit temperature performance
  - Music wire limited to 120°C

2.0mm, 1.1mm,
0.8mm, 0.9mm, 0.7mm
???



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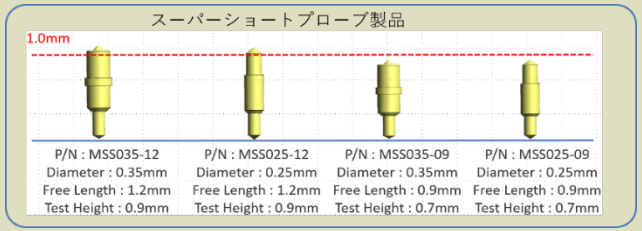
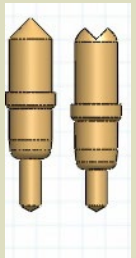
Test Tooling Solutions



SER Corporation



Signal Integrity

Leeno

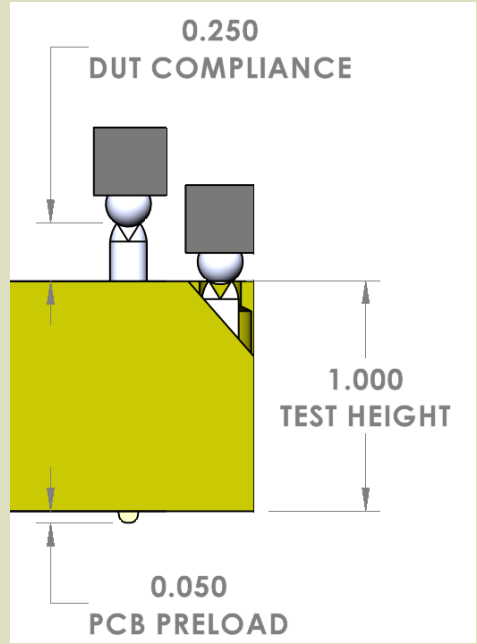
Electrical Challenges → Solution Opportunity

- Compliance:
  - Maximize - 0.300mm or more
  - Predictable and reliable spring force
  - PCB preload – eliminate PCB wear
- Operating Temperature
  - Want consistent force and Cres at -65° to +175° C
- RF performance
  - Low inductance
  - Good S_{11}, S_{22} response
- Simple contactor maintenance

The Solution:

HF Probe Family

- 4 Pitches: 0.3, 0.4, 0.5, 0.8mm
- Standardized 1.0mm Test Height
- 0.30-0.35 probe compliance
- Pd Alloy radial DUT plunger
- Designed for maximum RF configurability: J-Tuning



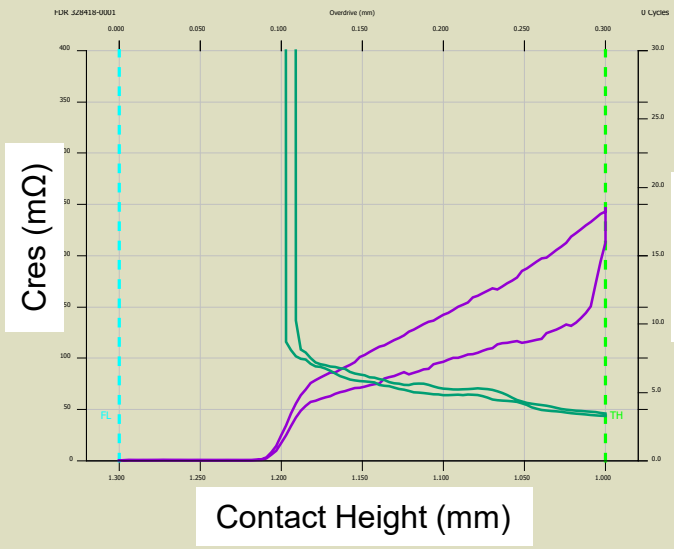
HF Family Solution

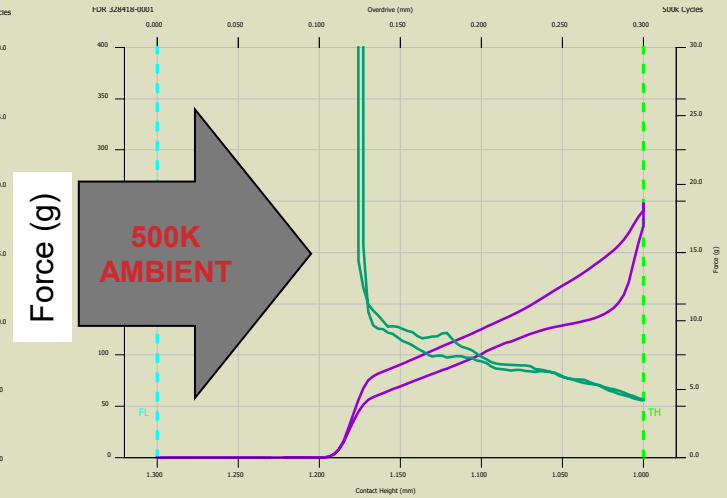
- Contactor construction
  - Standard CNC machined housing components for quick fabrication – no special tooling required
  - BGA / LGA / QFN – any configuration
  - Spear or crown tip probe option available
- Probe
  - Individually user replaceable
  - Cleanable Pd alloy – inline or manual cleaning
  - Patent-pending innovative probe architecture
- True configurability
  - Socket design improved with optimal probe size for application – *J-tuned™*
    - Optimize for RF performance (match impedance)
    - Optimize for power – use largest pin
    - Optimize for signal isolation

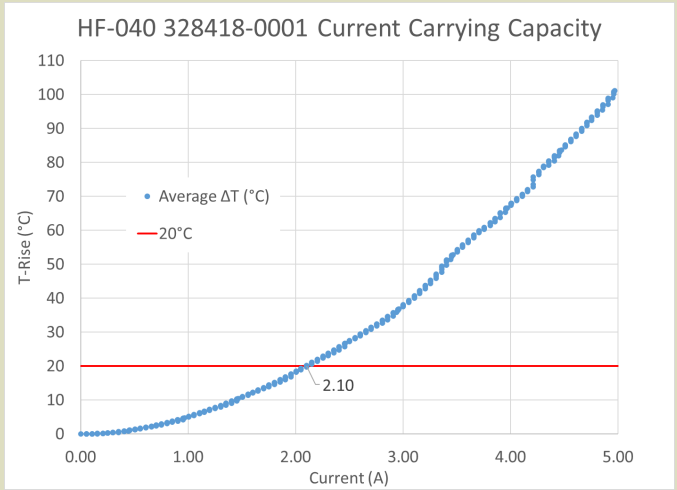
HF Probe Performance – In-house Qualification

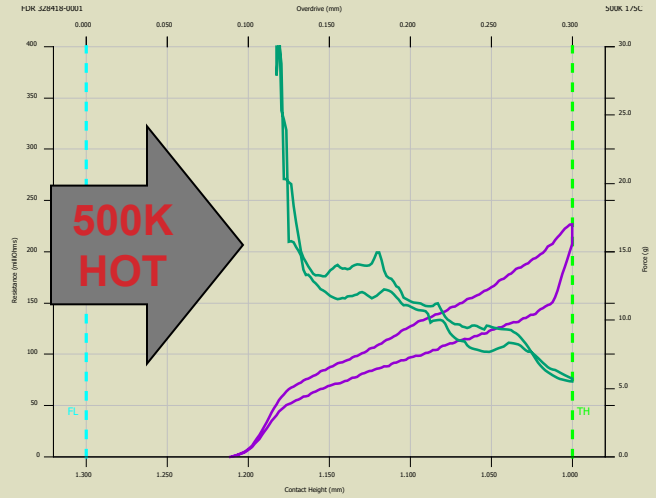
Qualification regimen – done for each probe configuration:

- Life cycle testing to 1M insertions
  - FDR testing periodically
  - Cres repeatability
- Life cycle testing at 175°C to 500K insertions
  - FDR testing periodically
  - Cres repeatability
- CCC T-Rise
- RF testing – GSG
  - HFSS model correlation





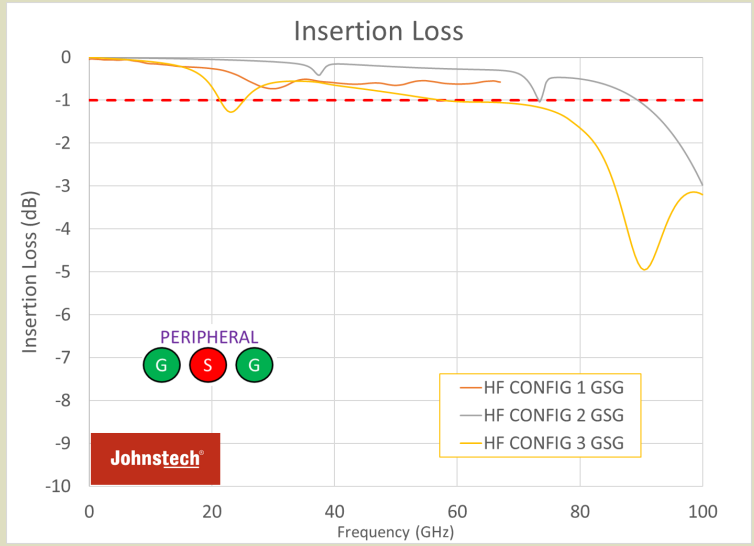




Example data for HF 040 variant

RF Qualification

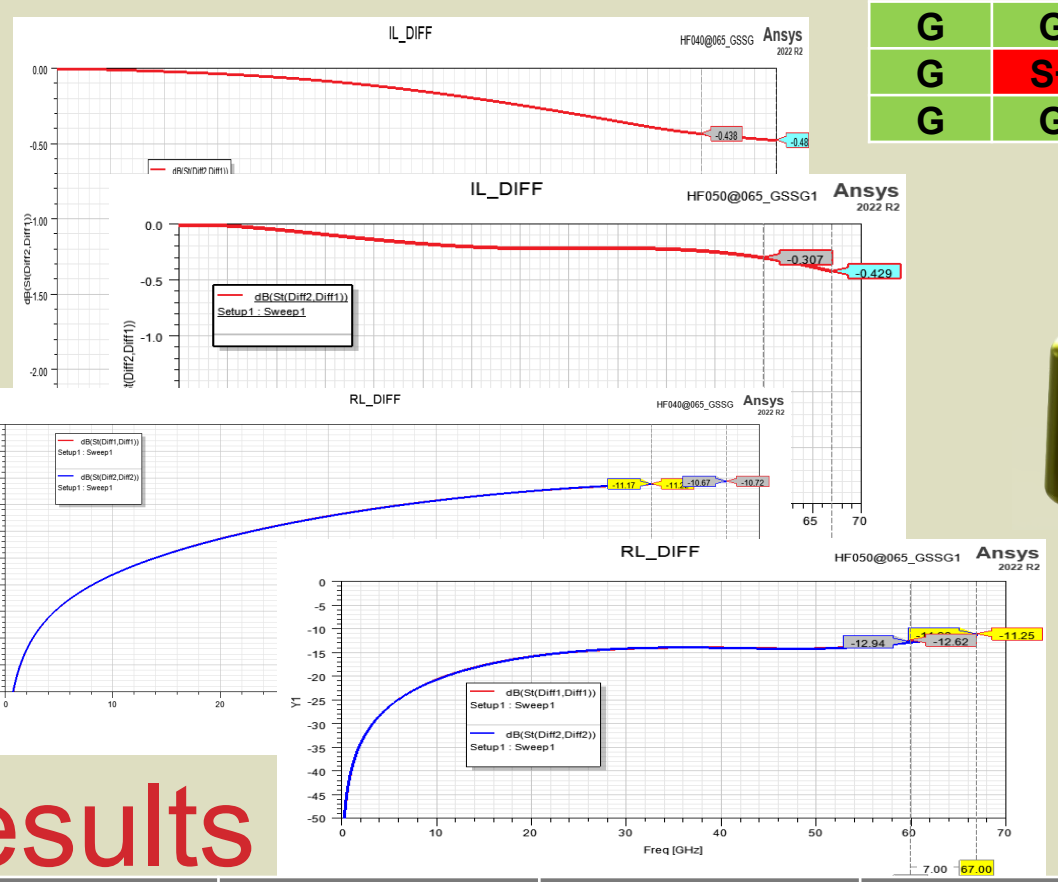
- Vector Network Analyzer Measurement
  - Keysight 67GHz N5227B PNA
  - Direct probing using CPW microwave probes
- Measurement correlation to HFSS models
  - All probe configurations
  - Certifies that simulation will be accurate



mmWave Transceiver Application

- 0.65mm FC-CSP package
- HFSS Modeling:
  - 4x3 Probe matrix
  - Tx and Rx Differential RF signals deep in BGA array
  - DC-67 GHz sweep
- Goal:
  - Differential Insertion loss <1 dB or better @67 GHz
  - Differential Return loss better than -10 dB @67 GHz
  - Find optimal HF probe configuration

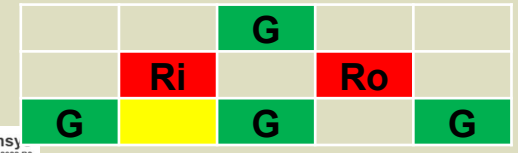
G	G	G	G
G	S+	S-	G
G	G	G	G



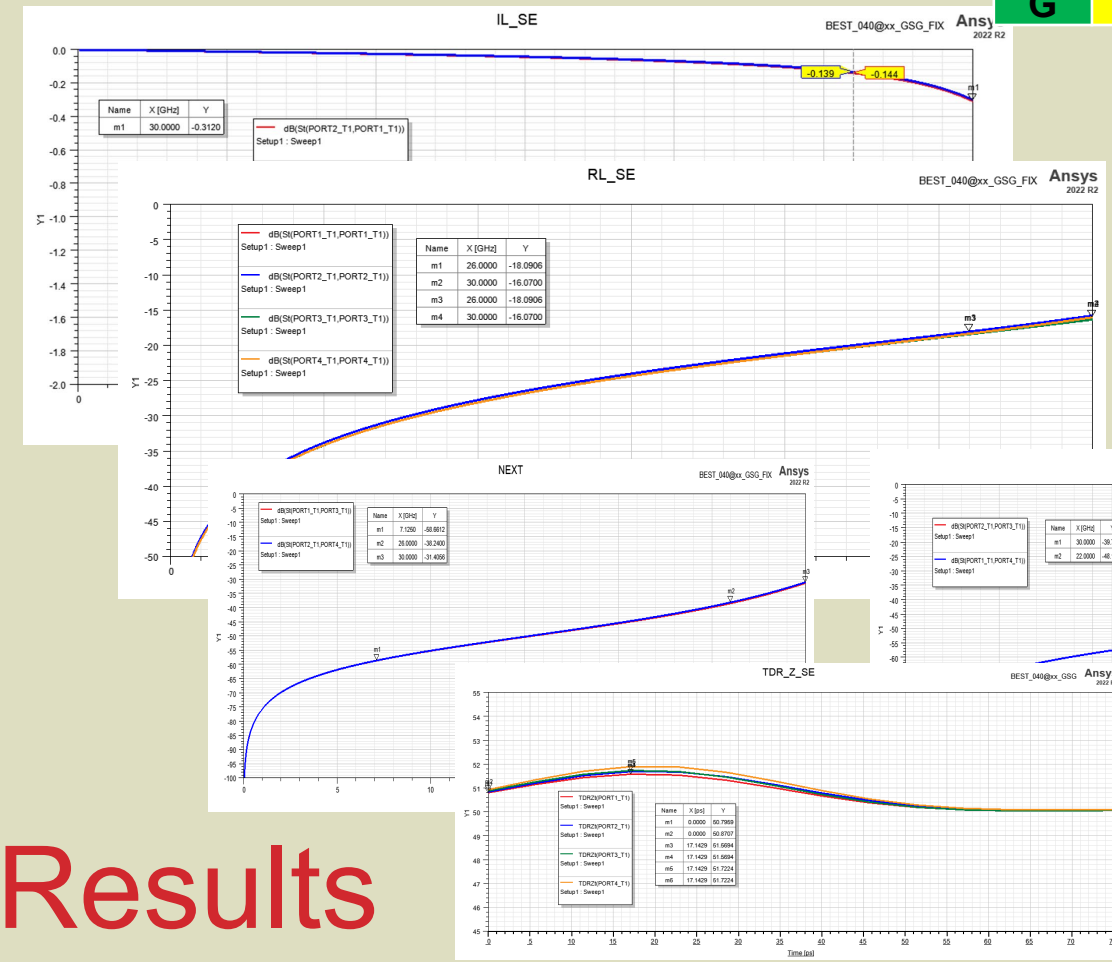
Results

Configuration	Insertion Loss at 67 GHz	Return Loss	Impedance (Diff)
HF A	-0.48 dB	-10.7 dB	107-114 Ω
HF B	-0.43 dB	-11.2 dB	86-100 Ω

RF Switch Application



- Variable pitch WLCSP package
- HFSS Simulation:
  - Variable pitch bump (.38mm min)
  - Internal RF_{in} and RF_{out} ports
  - DC-26 GHz sweep
- Goal:
  - Single-ended GSG insertion loss <1dB
  - Single-ended return loss better than -10 dB @30 GHz
  - Good isolation between RF_{in} and RF_{out}

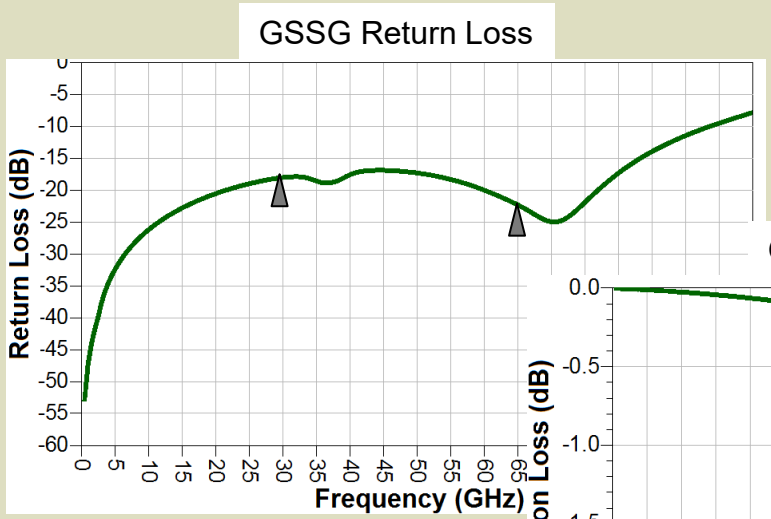


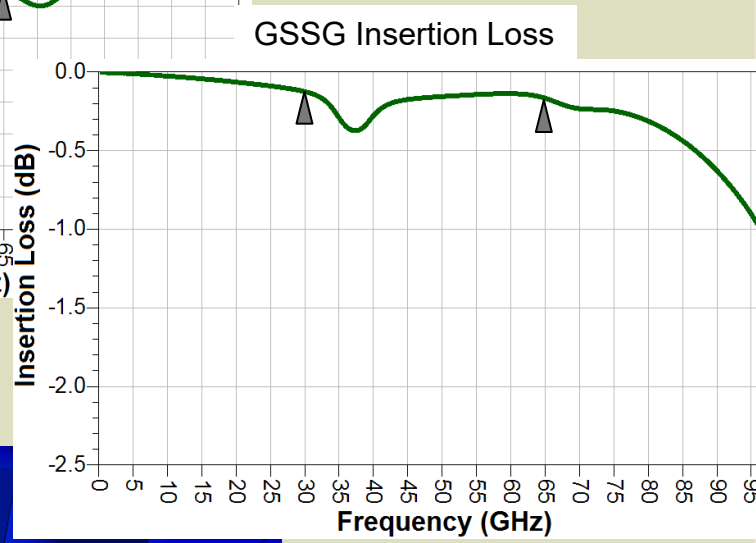
Results

Insertion Loss at 26 GHz	Return Loss at 26 GHz	Impedance (Hanning)	Isolation NEXT at 26 GHz	Isolation FEXT at 26 GHz
-0.144 dB	-10.7 dB	51.4 Ω	-38.24 dB	-44.00 dB

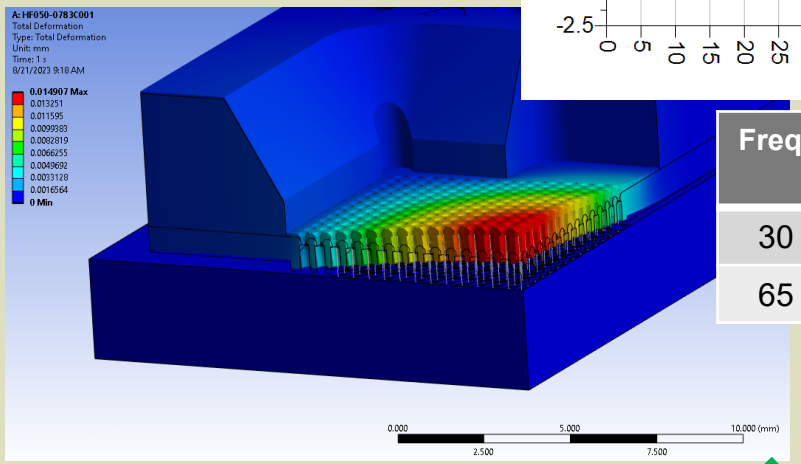
Optical DSP Transceiver Application

- Large 800 ball+ 0.5mm FCBGA package
- HFSS Modeling:
  - Tx and Rx 100Ω differential embedded in BGA array
  - 30GHz and 65GHz bandwidth signals
  - DC-100 GHz sweep
- Mechanical FEA Modeling:
  - Full design mechanical simulation – housing deflection
- Goals:
  - Differential Insertion loss <1 dB or better @30&65 GHz
  - Differential Return loss better than -10 dB @ 30&65 GHz
  - Find optimal HF probe configuration
  - Verify BGA array will not deflect housing beyond probe preload capabilities





Results

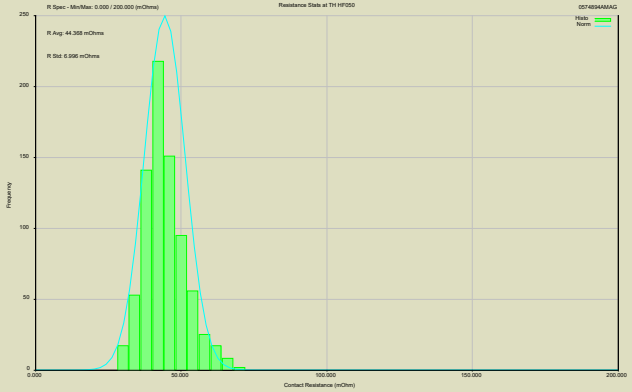


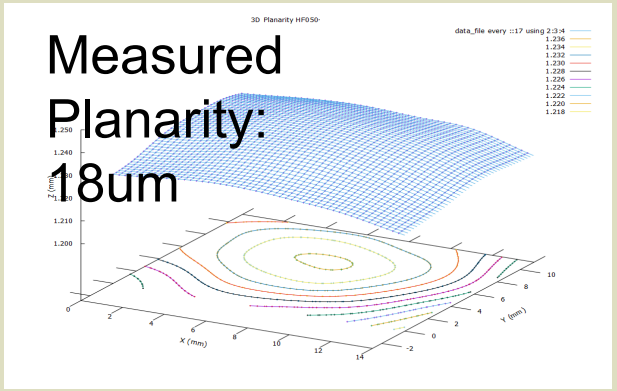
Frequency	Insertion Loss	Return Loss
30 GHz	-0.15 dB	-17 dB
65 GHz	-0.20 dB	-22 dB

Max HSG Bowing
15 um

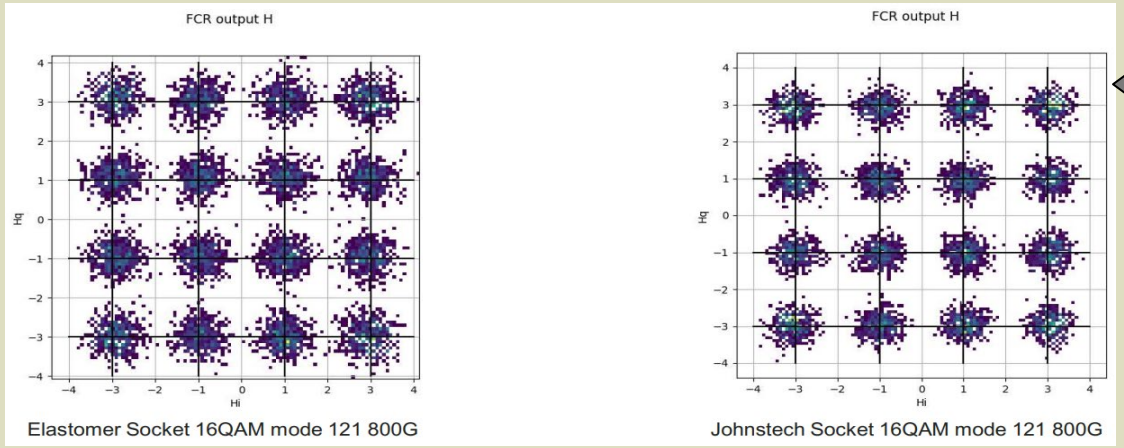
Optical DSP Transceiver Application

- Outgoing Measurements:
  - Probe Cres
  - Probe Force
  - Socket Probe Planarity
- Customer RF Performance
  - Digital 800G/16-QAM loopback test vs POR elastomer socket





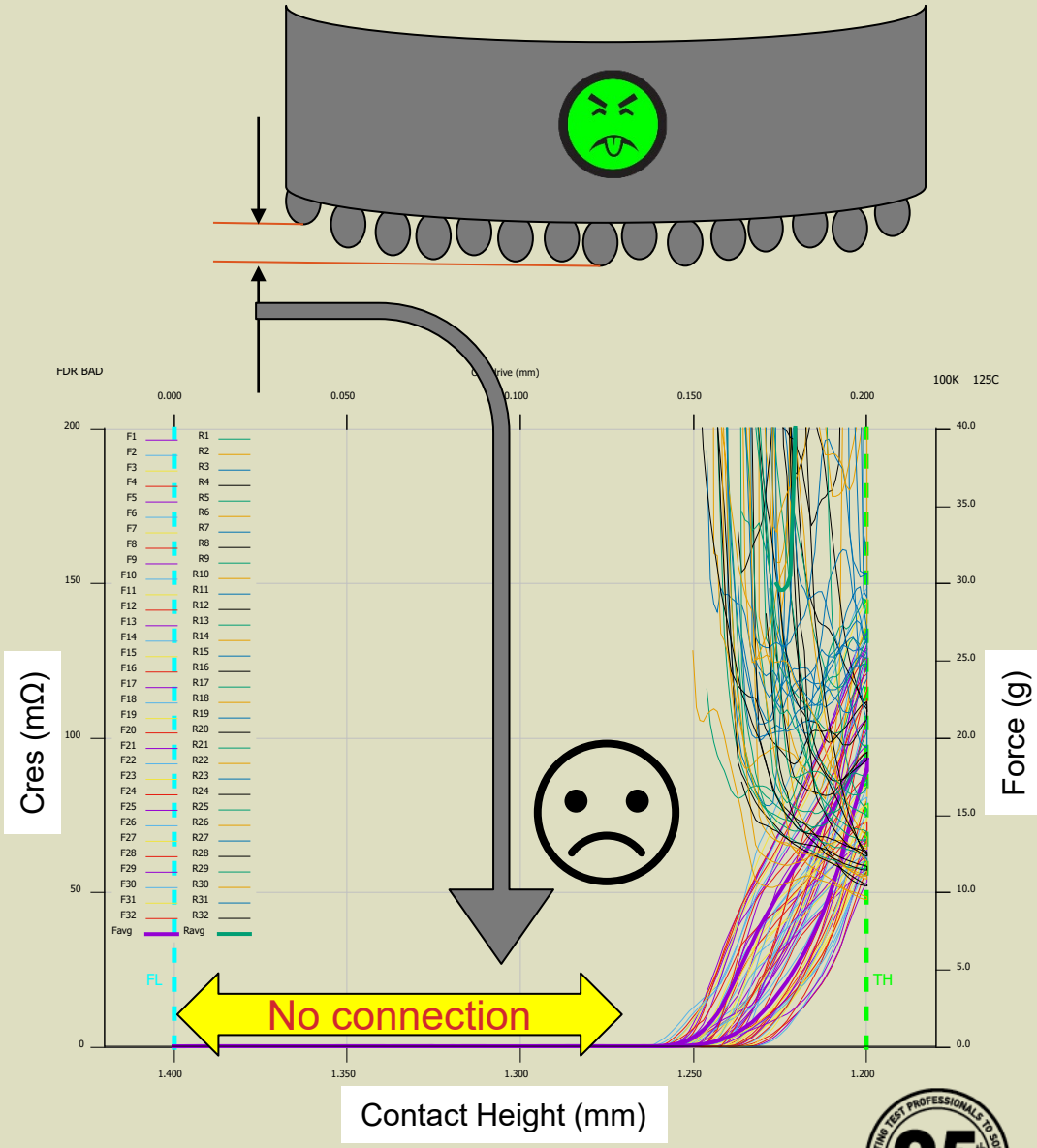
Probe Force (g)	Cres (mΩ)	Housing Deformation - Planarity (um)
13.9 Avg	44.4 Avg	18
1.3 St Dev	7.0 St Dev	



Tighter distribution

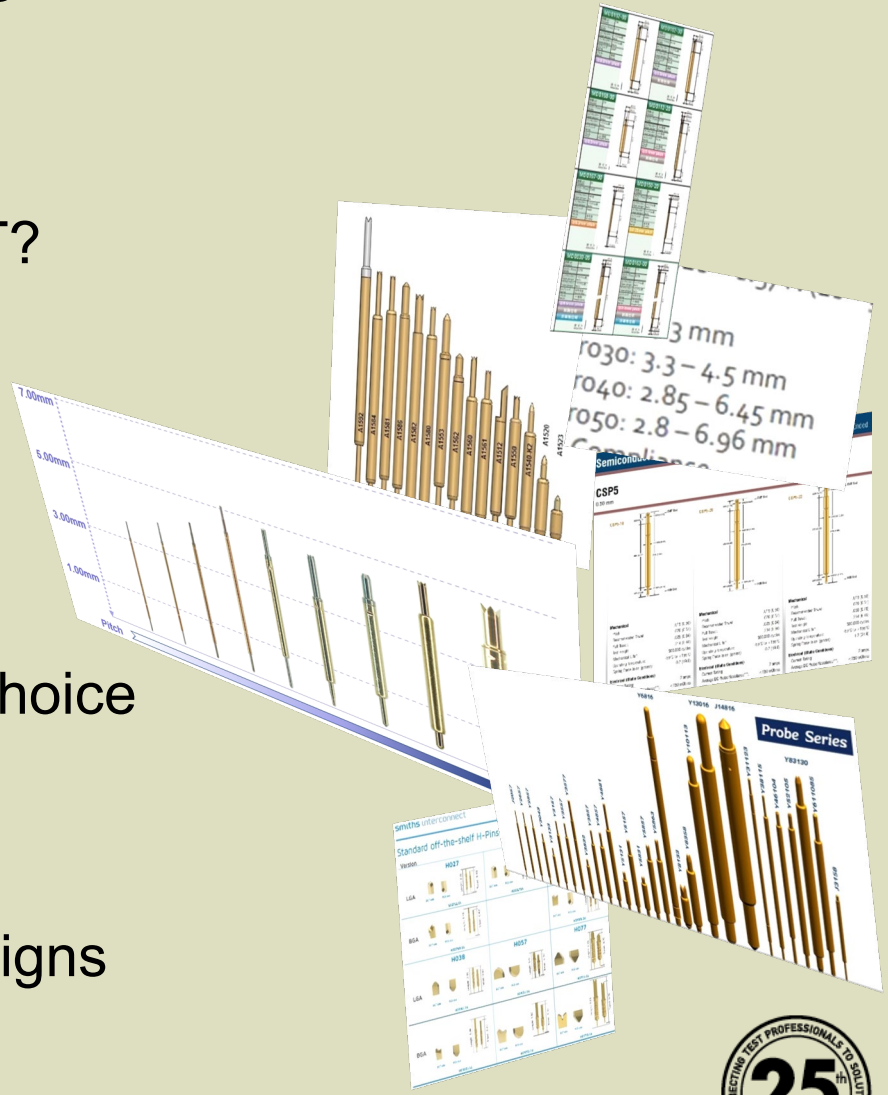
Mechanical Challenges – Limitations

- The vast majority of applications do not need 60+ GHz performance
  - 30 GHz is adequate
  - Run very high volumes and have world-wide established test cell infrastructure
- Most existing spring probe solutions
  - Different compressed test heights of every probe – limits the selection
  - Spring materials used limit testing below 155°C
  - Old designs use barrel and plunger fits that do not provide good biasing
  - Do not provide a wide operating window



Mechanical Challenges & Existing Solutions

- Maximize mechanical compliance to overcome handler and package shortcomings
  - Package specs – planarity/ball size/thickness
  - Handler stack-up – kit tuned to optimally compress DUT?
- Many spring probes to choose from many suppliers:
  - Double-ended
  - Single-ended
  - Many are temperature range is limited due to material choice (music wire)
- Way too long: poor electrical performance
  - 5.05mm? 7mm? 3.2mm? More? Many are legacy designs



Mechanical Challenges – Opportunities

- Compliance:
  - Maximize – provide best in class
  - Wide operating range to maximize yields
- Operating Temperature
  - Want consistent force and Cres at -65° to +175° C
- RF performance
  - Still plenty of RF margin – Measured probe performance to 30 GHz
  - < 1nH inductance
- Simple maintenance

The Solution: HC Probe Family

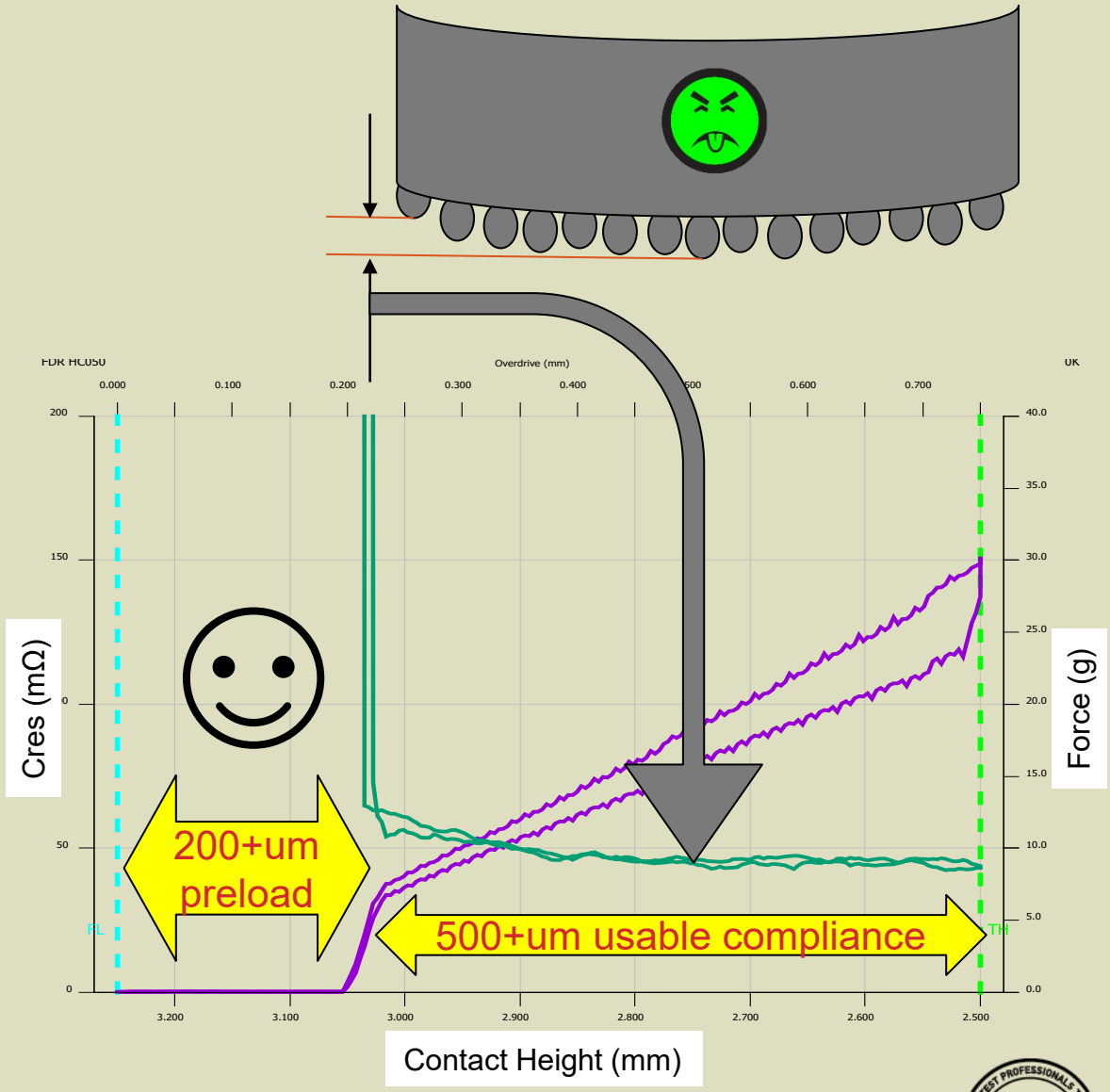
- 4 Pitches: 0.3, 0.4, 0.5, 0.8mm
- Standard 2.5mm Test Height
- **0.65-0.75mm** probe compliance - most compliance & spring force per test height
- Pd Alloy DUT plunger
- Stainless steel alloy spring for +175°C performance
- Also designed for maximum RF configurability and *J-tuning™*

HC

HF

Everyday HC Solution

- The HC spring probe family:
  - Uses same patent-pending architecture as HF
  - Up to 0.750 mm total probe compliance
    - Allows for an extreme range of test robustness
    - 2.5mm testing height
    - 175°C
  - Same RF configurability
- *MORE TO COME…….*



Summary

- For ‘bleeding-edge’ electrical challenges
  - Standardized 1mm short compressed height spring probes (HF)
    - Provide low inductance – maximize RF signal performance
    - Are flexible for optimal RF configurations
    - Provide the best mechanical compliance at 1mm TH
- For ‘bleeding-edge’ mechanical challenges
  - Standardized 2.5mm compressed height spring probes (HC)
    - Best in class compliance to accommodate mechanical stack-ups
    - Yet offer good RF performance and configurability