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# Flat Probe Technology for RF Test

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## Agenda

- RF Application Requirements
- History of Flat probe tech
- Factors that impact Probe RF performance
- RF Design of Flat probe tech
- Radial vs Flat Probe Measurements
- Application Results using Flat Probes
- Future Direction of Flat Probe technology

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## RF Market Drivers

Demand for instantaneous data transfer is driving high frequency, high bandwidth RF devices

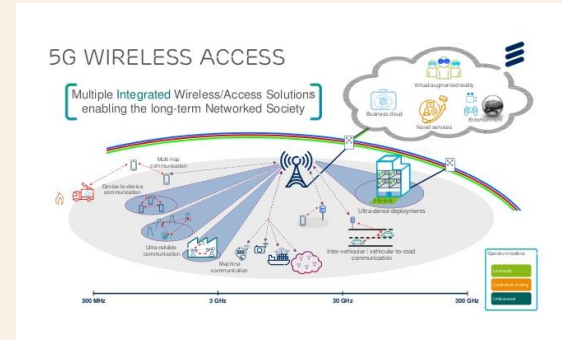
### Applications

- WiGig, 5G, Auto Radar, High-Speed Networking

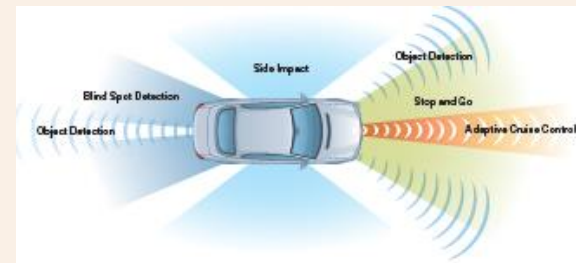
### Devices

- RF Transceivers, Power Amplifiers, Low Noise Amplifiers, RF Switches, SERDES, etc.

### 5G Backhaul



### Auto Radar



### 802.11AD (WiGig)



## RF Contact Requirements

- Low loss (>40GHz)
- High isolation (>60dB)
- Low inductance (<0.1nH)
- Matched impedance ( $50\Omega \pm 5\%$ )
- Low cost of test


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## BiTS Workshop 2007

- Gemini

### Challenges With Current Fine Pitch Probe Architectures

- Probe Z Axis Compliance
  - Fine pitches typically dictate the need for long probes
    - Low spring forces - very fine springs required
    - Higher contact resistance ( $R_c$ )
    - Low current carrying capacity (CCC)
    - Low bandwidth, high inductance
  - Some short probe designs exist, but have limited compliance
  - Probes tend to be very fragile
- Internal Resistance Consistency - Biasing
  - need consistent contact between plunger(s) and barrel components throughout compression
- Tip Geometries
  - Limits to DUT tip style, excessive PCB wear due to point loading



BITS 2007 3

- Performance

### Next-Gen Probe - Cantilever Biased

- 4 piece architecture - barrel-less
- Quad-cantilever arm biased
- Bias force is independent of spring force
- High compliance to test height ratio
- Dual springs - 30g+ force at fine pitch (.4mm)



Gemini™  
ECT Patent  
Pending

BITS 2007

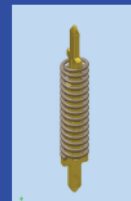
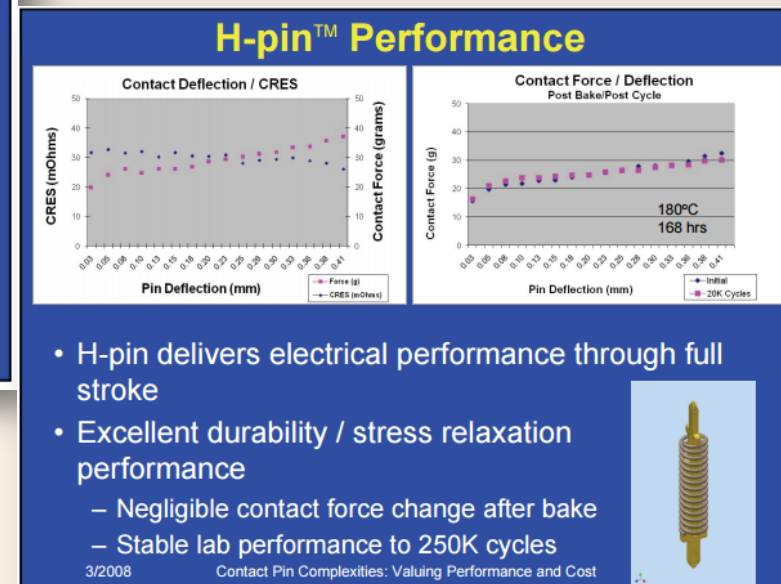
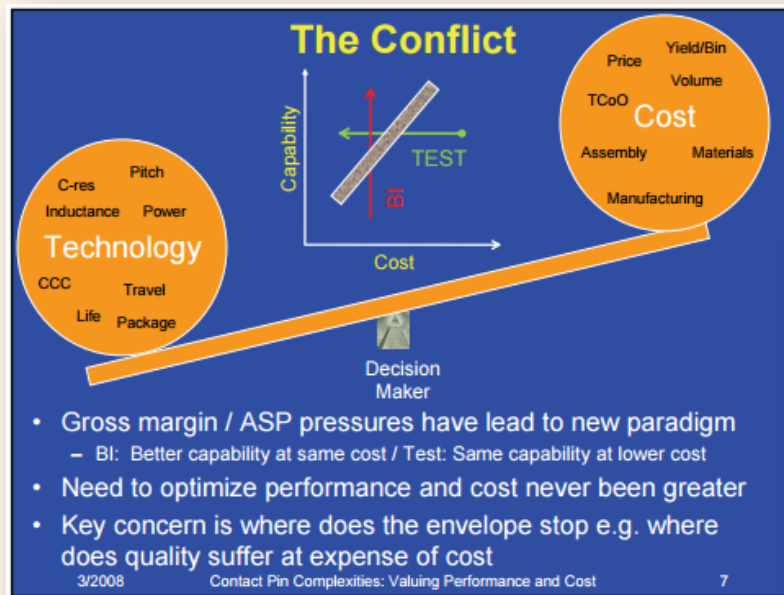
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## BiTS Workshop 2008

- H-Pin

- Performance and Cost





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## BiTS Workshop 2012

- Stamped Probe
- High Volume

### Why Trials on Stamped Spring Probe?

- Easy for mass production and lead time management
- Easy for quality management
- Low cost enabling wider application of probe pins
- Finer pitch
- Shorter length for high speed test

03/2012

High Volume Low Cost Stamped Spring Probe Development

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### Three Piece Spring Probe Pin by Stamping

- Example 2. Spring probe pin with three bridges



03/2012

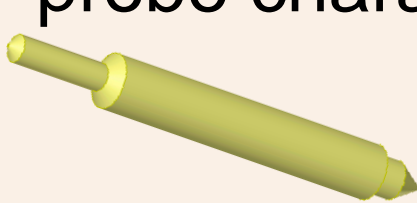
High Volume Low Cost Stamped Spring Probe Development

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## Flat Probes

- Many Flat probe options available today
- Are they a fad or do they truly add value?
- First lets look at what impacts probe performance
- Then we'll look at specific radial and flat probe characteristics



VS.



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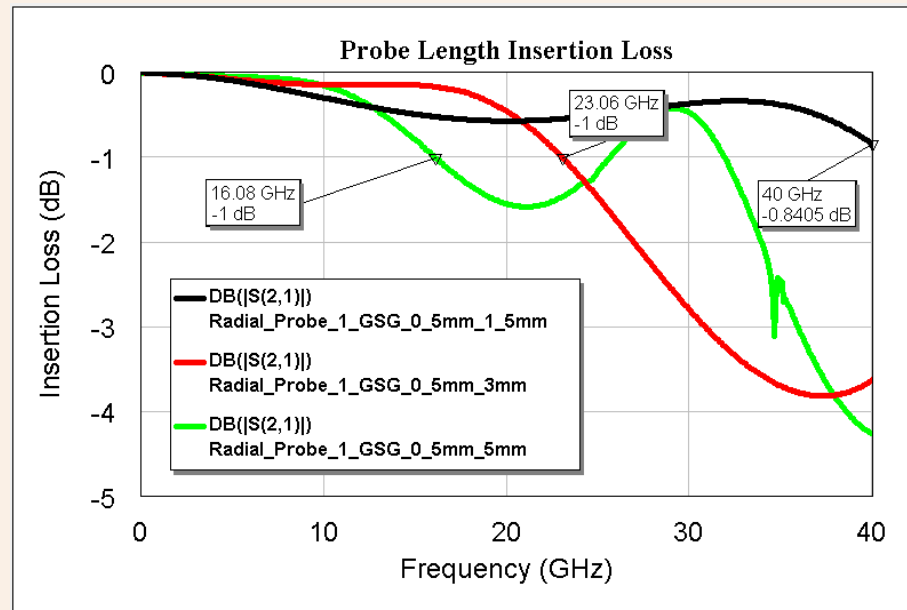
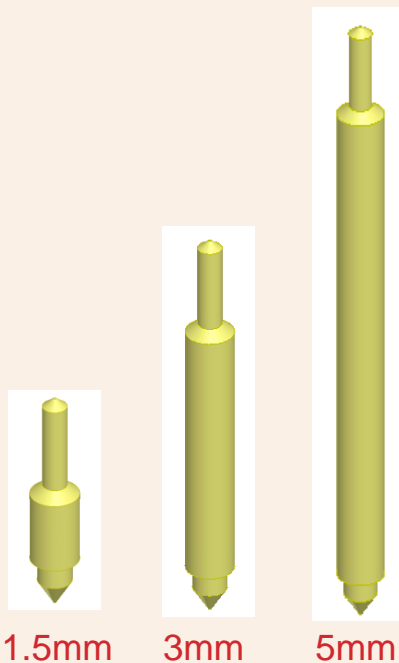
## Factors Affecting Spring Probe RF Performance

- Length (Major)
- Cross section (Major)
- Material (Minor)
- Tip design (Minor)
- Force (Minor)

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## Factors Affecting Probe RF Performance

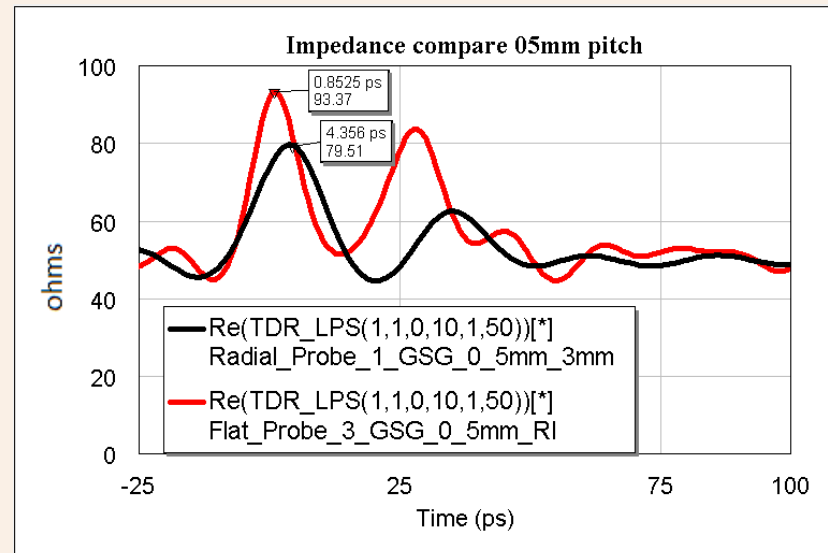
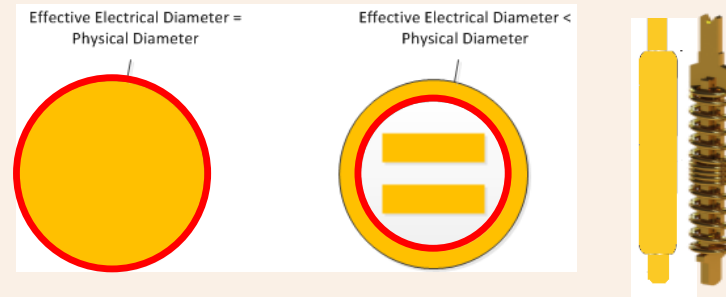
- Length of probe
  - Inverse relationship to bandwidth



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## Factors Affecting Probe Performance

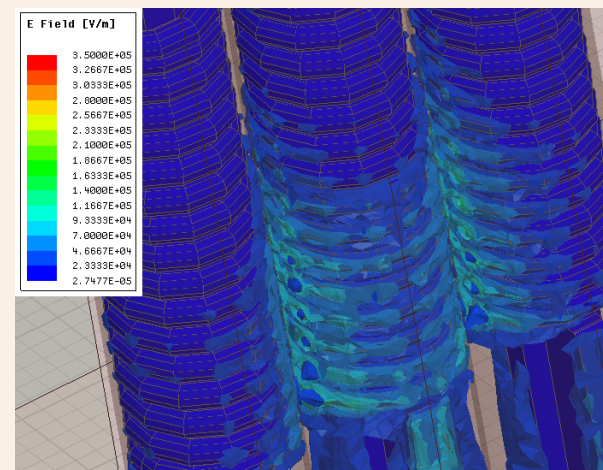
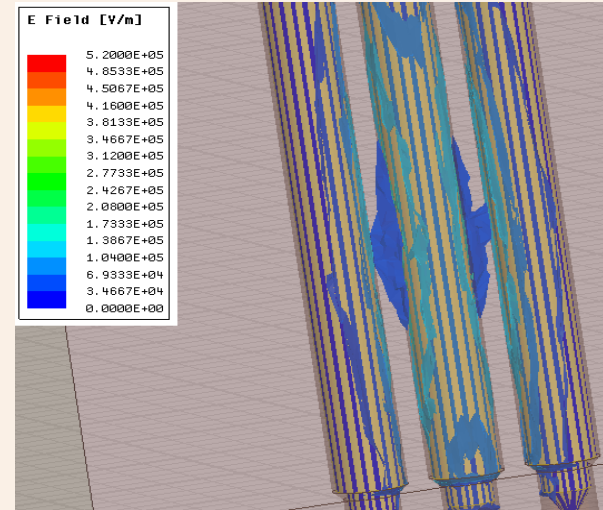
- Diameter of probe
  - At native pitches GSG of Radial probes is near 50 Ohms
  - Flat probes have smaller effective diameter than radial probes
  - Flat probes have higher impedance than Radial Probes of the same diameter



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## RF Factors - Skin Effect

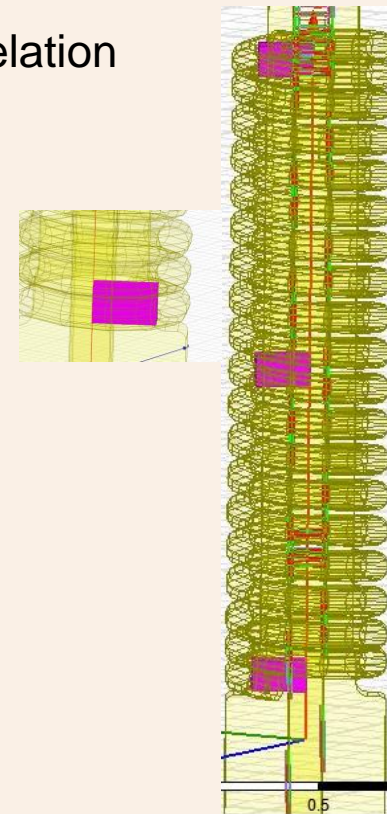
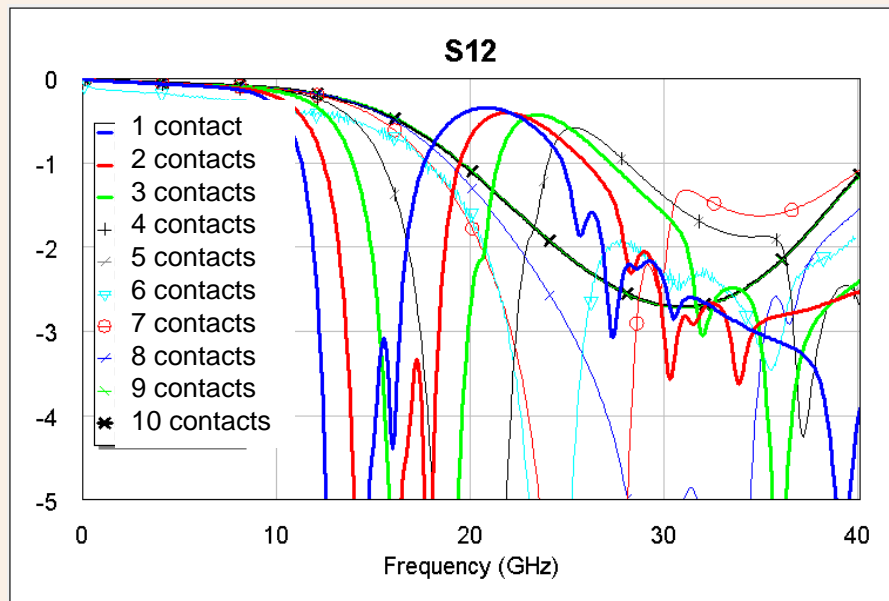
- Skin effect concentrates current on surface nearest return path
- Radial
  - Round
  - Solid Surface
  - Simple electrical model
- Flat
  - External Spring
  - Complex electrical model
  - Smaller effective diameter



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## Factors Affecting Flat Probe RF Performance

- **Must short the spring** to ensure consistent RF performance
- More windings shorted = better performance
- Minimum 3 contacts required for good RF correlation

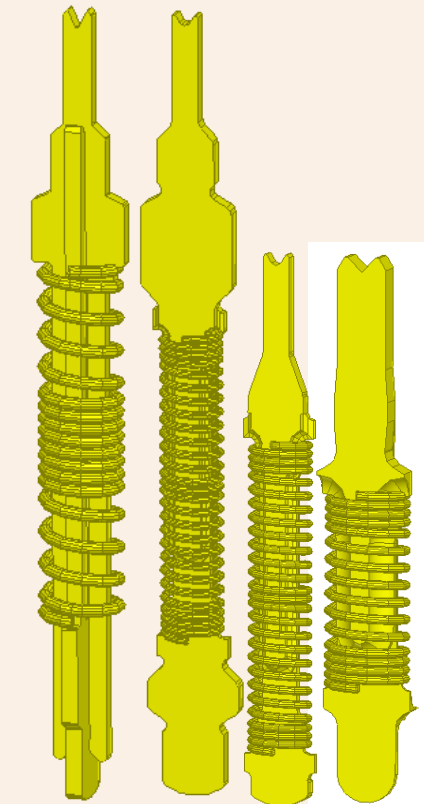
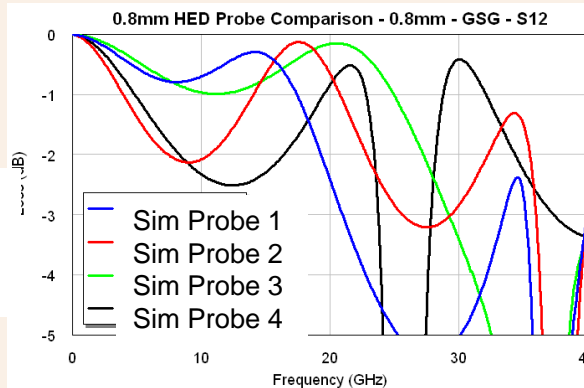
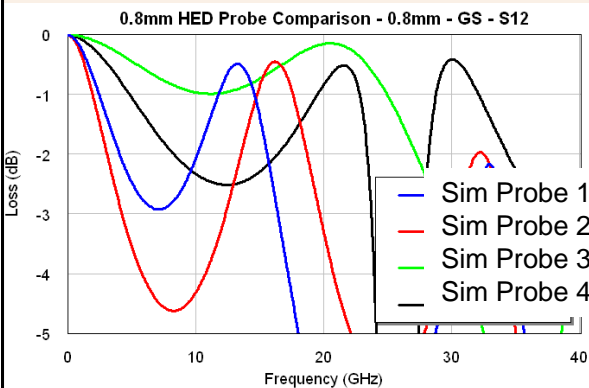


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## Various Flat Probe Simulation Results

- Results show very different performance depending on cross section and length

	Sim Probe 1	Sim Probe 2	Sim Probe 3	Sim Probe 4
<b>S12 GS (-1dB)</b>	<b>2.4 GHz</b>	<b>2.0 GHz</b>	<b>&gt;40 GHz</b>	<b>2.4 GHz</b>
<b>S12 GSG (-1dB)</b>	<b>17.4 GHz</b>	<b>4.2 GHz</b>	<b>25.0 GHz</b>	<b>4.9 GHz</b>



Sim Probe 2 Sim Probe 4  
Sim Probe 1 Sim Probe 3

- Flat probe RF performance is impacted by multiple design variables



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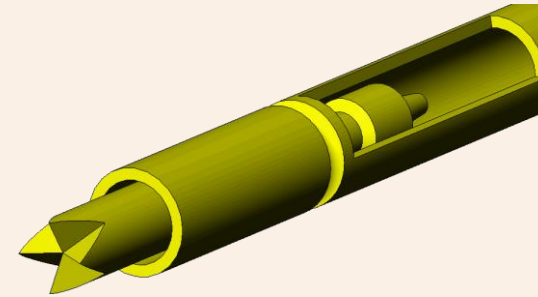
## Factors Affecting Contact Resistance Stability

- Length (Minor)
- Cross section (Major)
- Material (Minor)
- Tip design (Major)
- Force (Major)

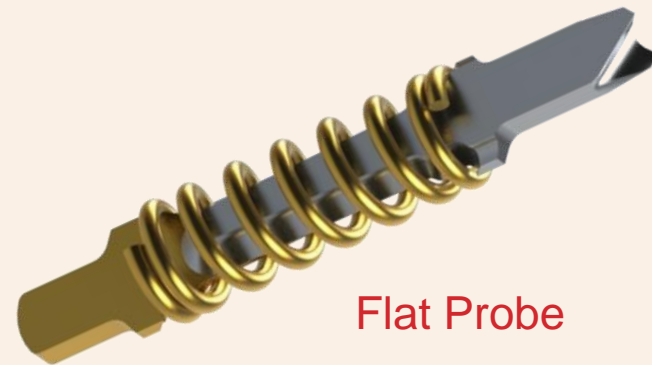
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## Factors impacting Contact Resistance

- Radial
  - Internal surfaces require plating specification
  - Make/Break Barrel plating process causes layering
  - Barrel plunger contact 1 or 2 points
- Flat
  - Flat external plating surfaces
  - Large contact surface between top and bottom plungers
  - Improved biasing



Radial Probe



Flat Probe

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## Flat Probe Cross-Section Design

• Worst



• Bad



• Good



• Best

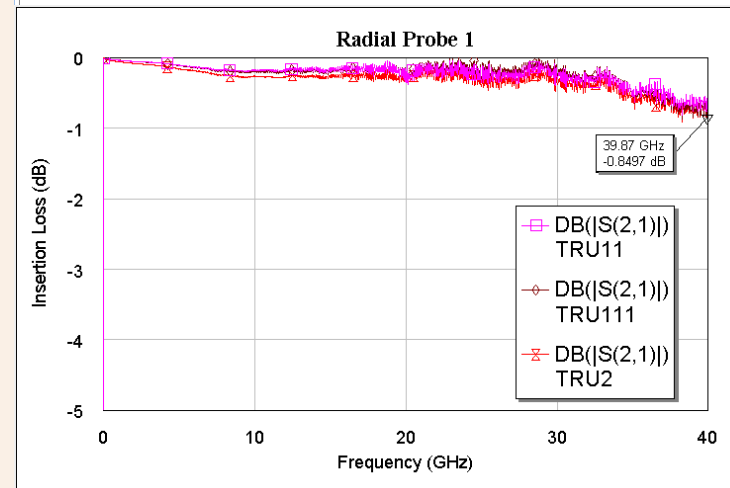
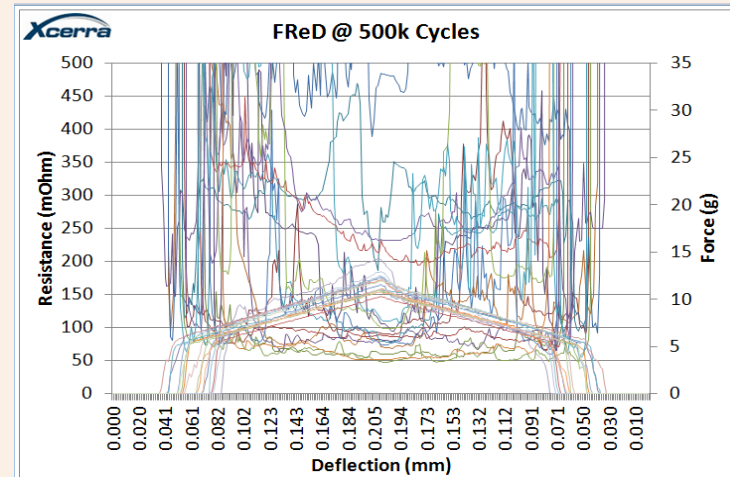
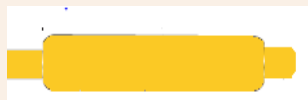


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## Radial Probe 1

- Short Single ended spring probe
- Consistent high bandwidth
- Low Force
- Contact resistance instability

Probe Characteristics	
Pitch	0.5mm
Diameter	0.38mm
Length	1.7mm
Force	15g

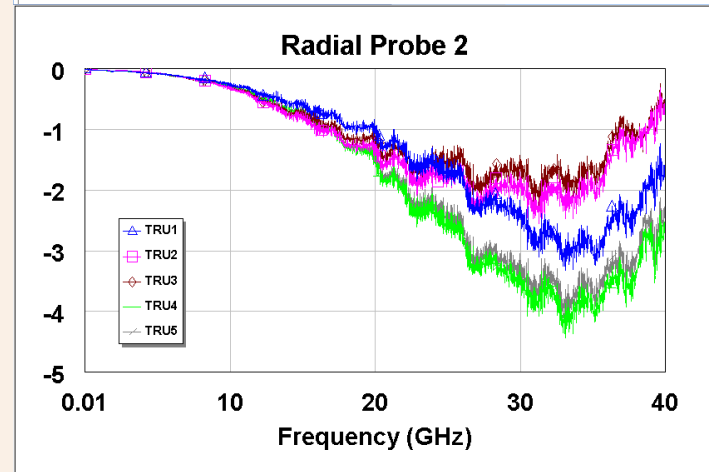
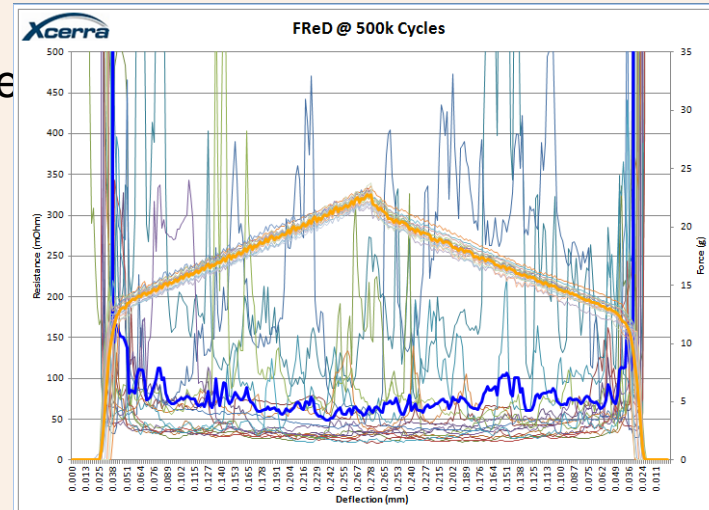
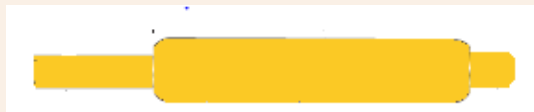


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## Radial Probe 2

- Standard single ended spring probe
- Average length
- Consistent bandwidth to 20GHz
- Contact resistance instability

Probe Characteristics	
Pitch	0.5mm
Diameter	0.3mm
Length	3mm
Force	30g



Flat Probe Technology for RF Test

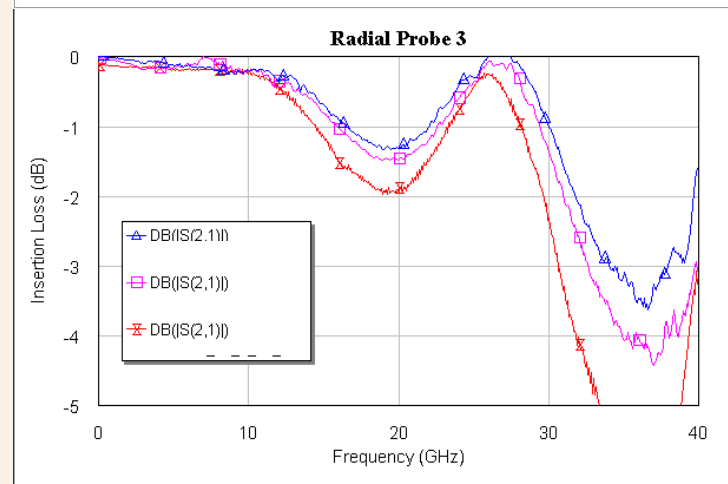
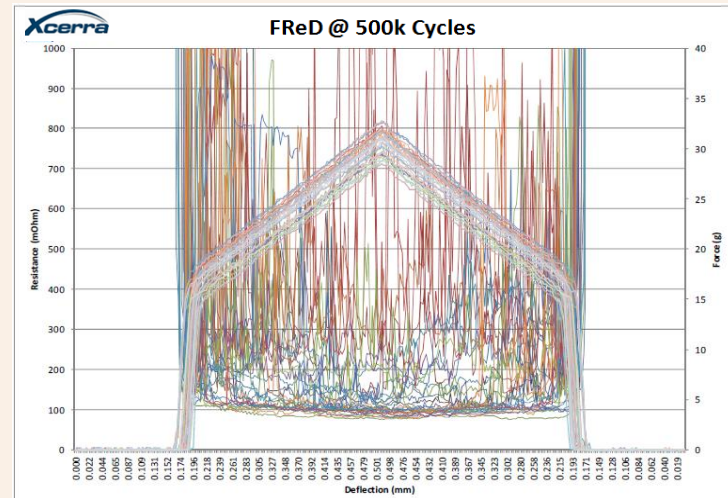
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## Radial Probe 3

- Long double ended spring probe
- High Impedance mismatch
- 15Ghz Bandwidth
- Contact resistance instability
- No internal bias

### Probe Characteristics

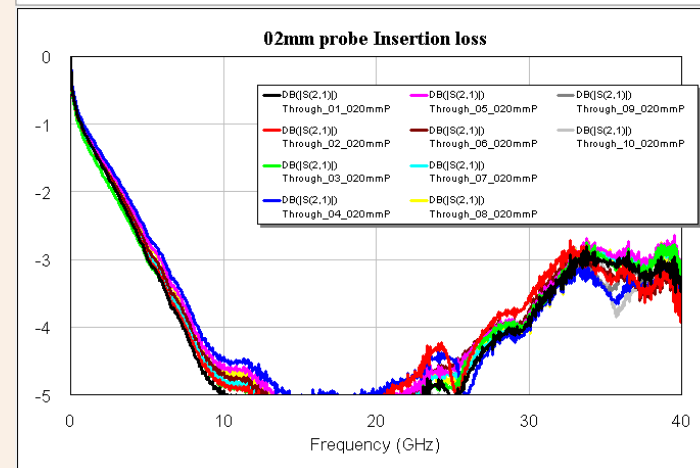
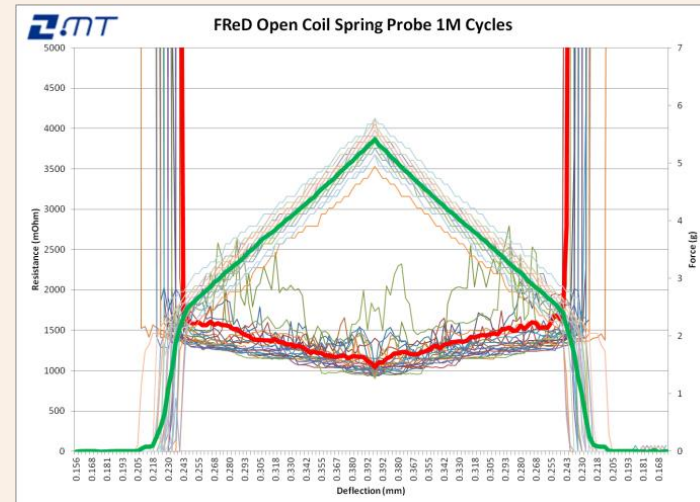
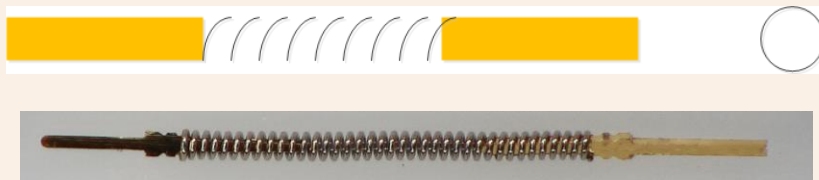
Pitch	0.5mm
Diameter	0.3mm
Length	6mm
Force	32g



## Flat Probe 1

- Long Flat Probe for WLCSP applications
- Spring is DC and RF Path
- Poor RF performance of spring inductor

Probe Characteristics	
Pitch	0.2mm
Diameter	0.1mm
Length	7mm
Force	6g

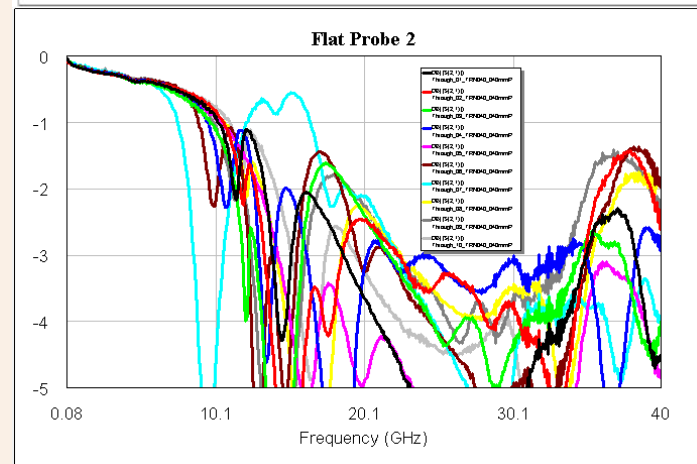
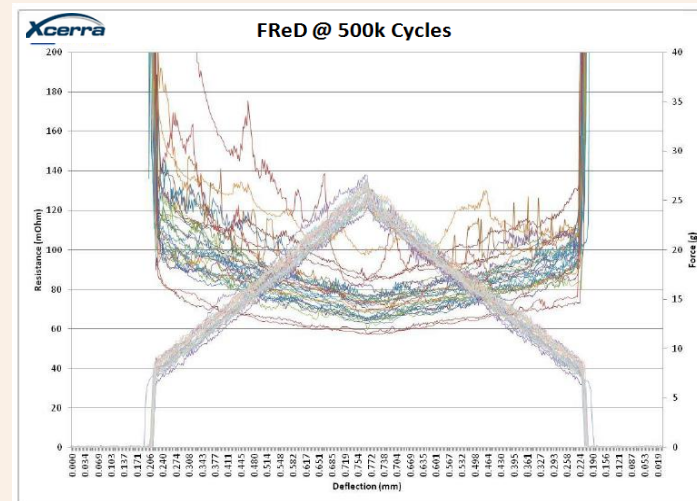


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## Flat Probe 2

- Standard double ended probe length
- Small Plungers
- Inconsistent spring contact causes resonance above 7GHz

Probe Characteristics	
Pitch	0.4mm
Diameter	0.33mm
Length	5mm
Force	25g



Flat Probe Technology for RF Test

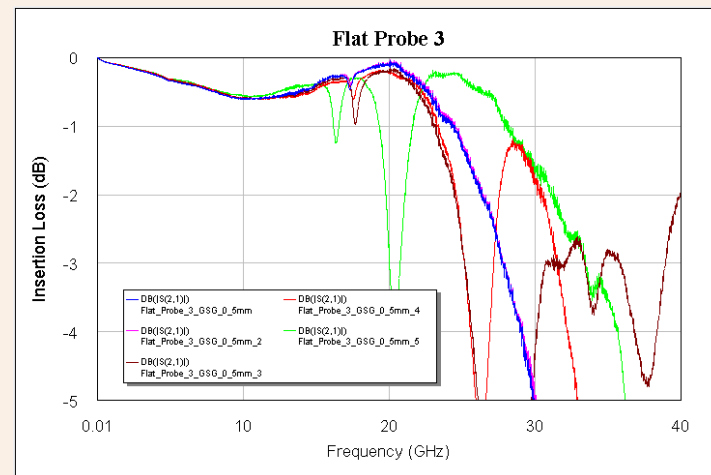
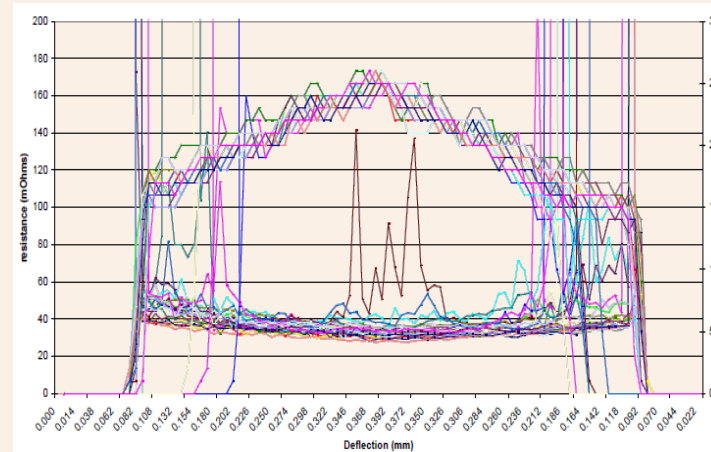


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## Flat Probe 3

- Standard single ended probe length
- Consistent resistance
- Minor spring resonance @17Ghz

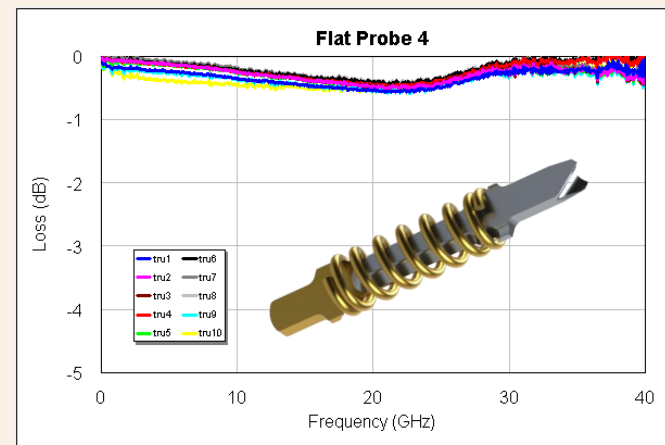
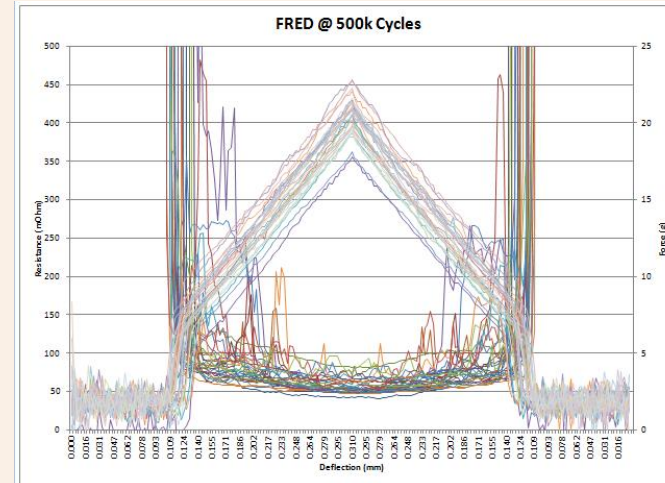
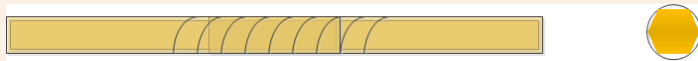
Probe Characteristics	
Pitch	0.5mm
Diameter	0.3mm
Length	3mm
Force	25g



## Flat Probe 4 - ACE

- Short Probe
- Large Plungers
- Consistent spring contact – no resonances
- Consistent and low resistance

Probe Characteristics	
Pitch	0.4mm
Diameter	0.29mm
Length	1.5mm
Force	17g

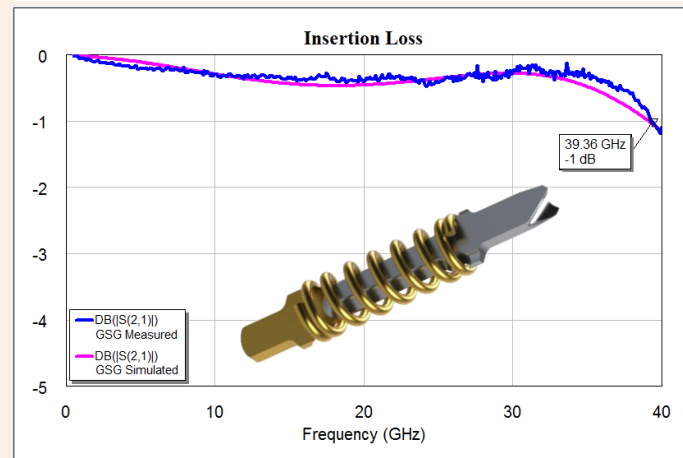
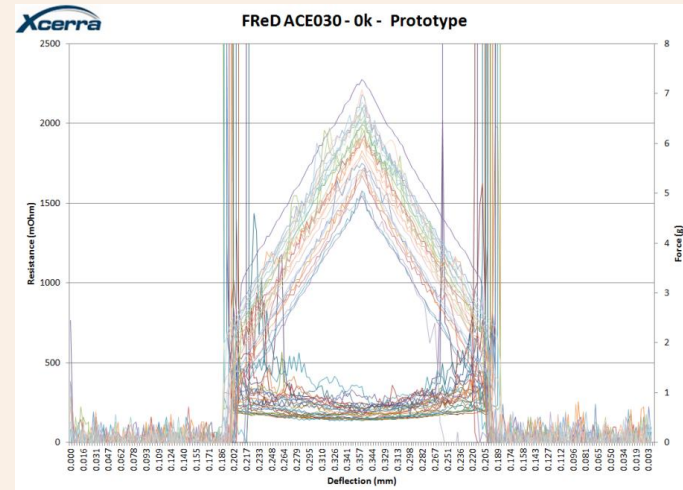
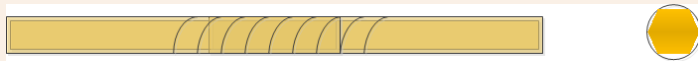


## Flat Probe 5 - ACE

- Short Probe
- Large Plungers
- Consistent spring contact – no resonances
- Consistent and low resistance
- Still in development stage, need to improve Mechanical stability

### Probe Characteristics

Pitch	0.3mm
Diameter	0.29mm
Length	1.5mm
Force	17g



## Application Feedback - ACE

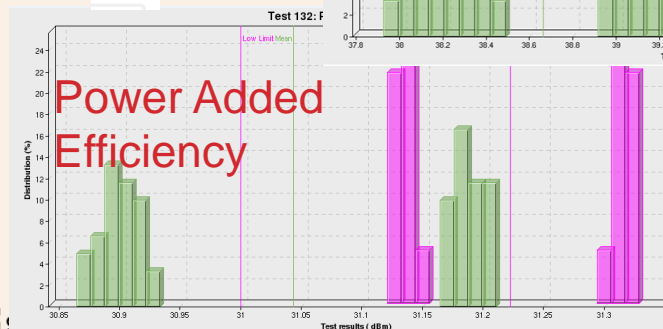
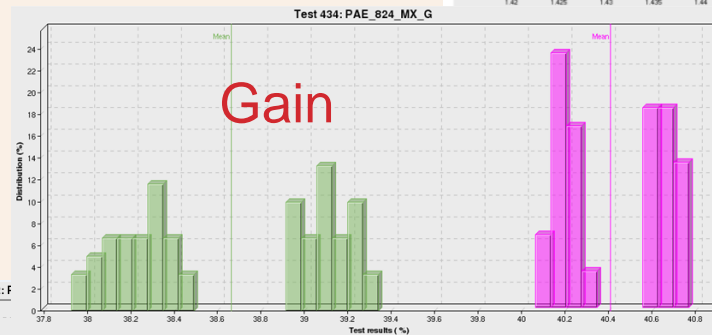
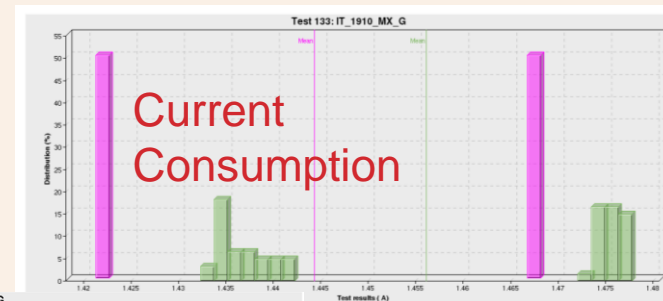
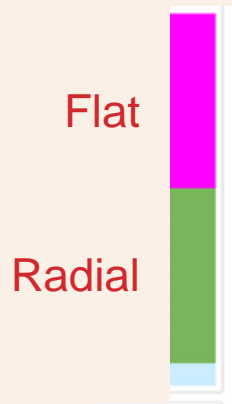


Parameters	Units	25.078 Gbps			28.05 Gbps		
		Solder	Socket	Delta	Solder	Socket	Delta
Tr	pS	15.74	17.54	-1.8	15.73	17.39	-1.7
Tf	pS	16.43	16.05	0.4	16.52	16.05	0.5
Jpp	pS	5.762	7.138	-1.4	6.721	7.59	-0.9
EYE Amp	Vpp	802	734.2	68	789	717.8	71
EYE Width	pS	33.6	33.11	0.5	29.95	29.82	0.1

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## Customer Feedback - ACE

- Flat has Lower Current Consumption
- Flat Standard Deviation is Less
- Flat results in higher Gain
- Flat adds 2% Power Added Efficiency



Flat Performance Wins!

## Conclusion

- You can in fact use Flat Probes for RF applications
- Flat Probes offer High Performance and Low Cost of Test
- Flat Probes For RF applications need to be designed and fabricated with care to avoid spring resonances

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## Flat Probe Roadmap: Atlas, ACE, Nexus

