SW Test Workshop
Semiconductor Wafer Test Workshop

WLCSP xWave for high frequency wafer probe applications

Jason Mroczkowski
Xcerra Corporation

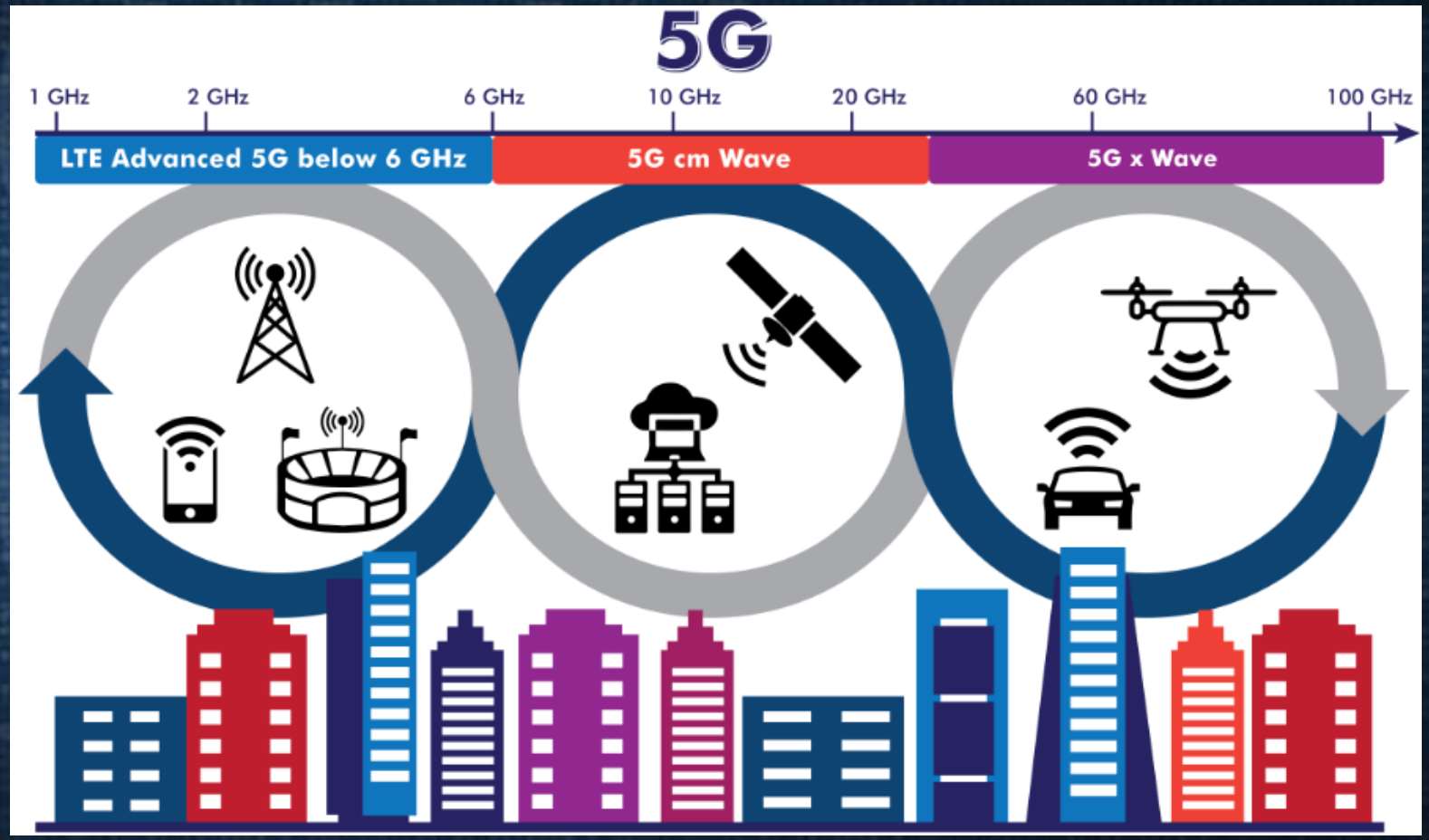
June 3-6, 2018

Overview

- Introduction / Background – cmWave and mmWave Market/applications and xWave
- Objectives / Goals – Move from package test to wafer test
- Methods / Materials / Procedures – design considerations, mechanical simulation, electrical simulation, characterization
- Results / Relevant Findings / Key Data – tip design, force, insertion loss, impedance
- Discussion of Results / Strengths / Weaknesses, etc. – minimum pitch, multisite
- Summary / Conclusion - viable cmWave and mmWave wafer level test solution
- Follow-On Work – Beta sites

RF Market Summary

- **The RF market has pull**
  - RF Component Market Growing to $22B by 2022
    - cmWave (3GHz – 30GHz) = $18.2B,
    - mmWave (30GHz-100GHz) = $4.6B
  - Rapid growth in mmWave applications
    - ADAS, 5G telecom UltraGig, WiGig, and Satellite devices
    - **up to 40% CAGR through 2022.**



mmWave Market

- **ADAS**
  - Advanced Driver Assistance System (Automotive Radar)
  - Short Range 24GHz and Short and Long Range 80GHz versions
  - CMOS – Low cost, High integration, catching up with SiGe
  - SiGe – High power/frequency performance ,High cost ,Low integration
  - GaN – Highest frequency performance, high cost, low integration, being oboseted by SiGe
- **5G telecom**
  - 5G Backhaul – routers behind the tower
  - 5G End Node – Handheld phones/tablets/devices
  - Contacted test – external antenna arrays
  - AIP – Antenna In Package – Over the air test
  - 28GHz and 39GHz bands popular
  - Eband/Vband expected as next generation

mmWave Market

- **UltraGig/WiGig**
  - Fixed Wireless applications
  - Local area networks
  - Short range line of sight
  - beamforming
  - 57-64 GHz extended to 71 GHz

- **Satellite Internet**
  - Low orbit satellite internet systems
  - Global aircraft high speed internet connection
  - Terrestrial and orbiting devices
  - Ku (12-18 GHz) and Ka (26.5-40 GHz) bands
- **High Speed Cloud Networks**
  - SERDES - 54GBPS NRZ, 112GBPS PAM4
  - 3rd Harmonics reach 80GHz
  - RF theory applies to Digital applications

xWave Technology - Broadband Production Solution to 100 GHz

Best Signal Integrity

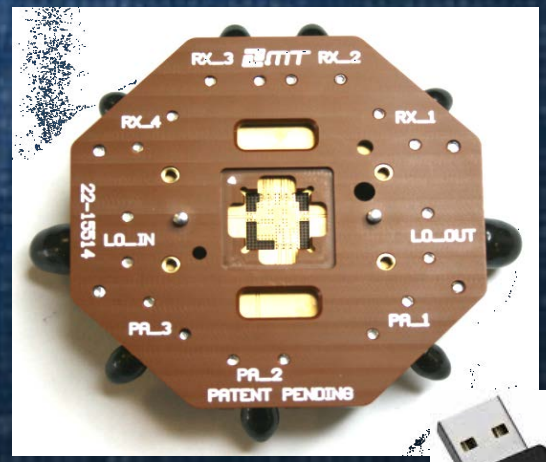
- New paradigm eliminates board and Pogo pins from RF path
- Shortest possible, coplanar waveguide
- Compatible with single-ended and differential signals
- Minimum number of transitions between Tester and DUT

Highly Integrated Solution

- Contactor includes entire path from tester to DUT
- Only power and control signals use board and Pogo pins

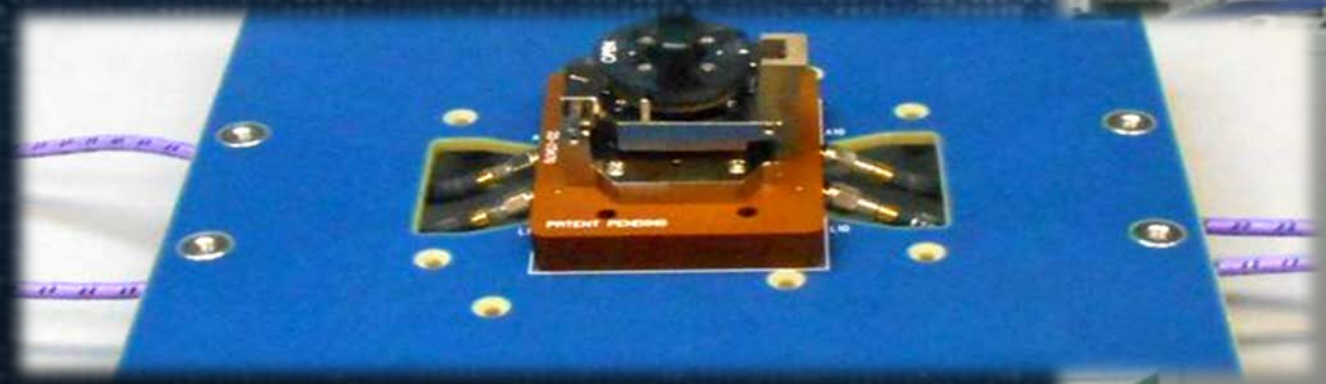
High-Volume Production Package Test Solution

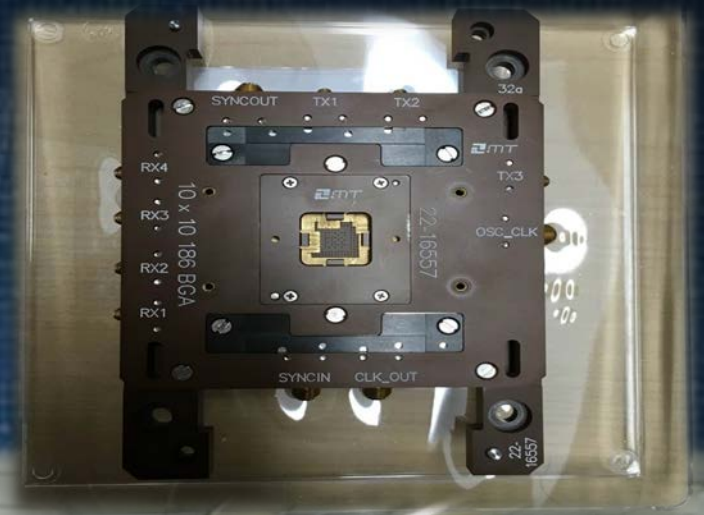
- *Not just a lab bench science kit!*
- 1.5 M+ cycles on original hardware
- Field-maintainable mechanical assembly
- Includes calibration kit
- Tri Temp Capable (-55 to 155°C)



xWave Contactor Field Results

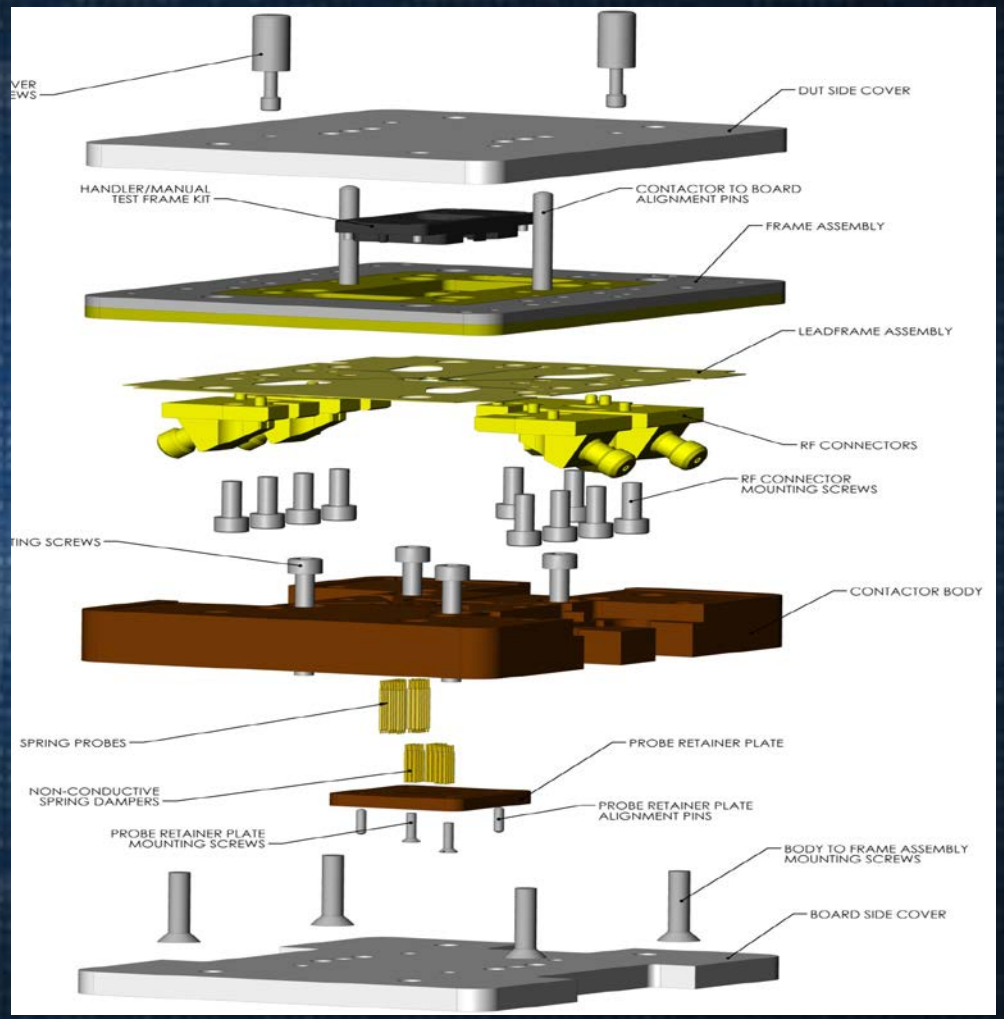
- Millions of cycles on original hardware
- Soldered-down device performance @ 80 GHz
- 100% Correlation between Lab and Production
- 80%+ Automotive Radar applications use xWave Contactors
- xWave used in production 5G, SERDES, Radar, and WiGig



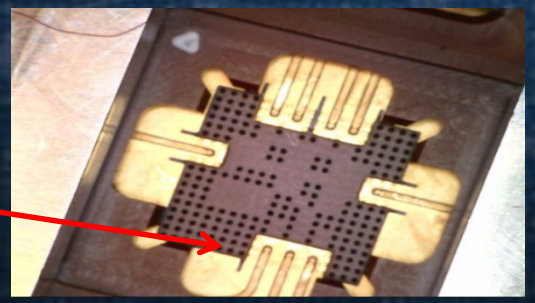


xWave: Designed for cmWave/mmWave RF Performance

- Minimized number of interfaces
- Best signal quality
- Highly reliable and robust
- Best suited for production environments
- Patent # 9842793
- Additional Patents Pending

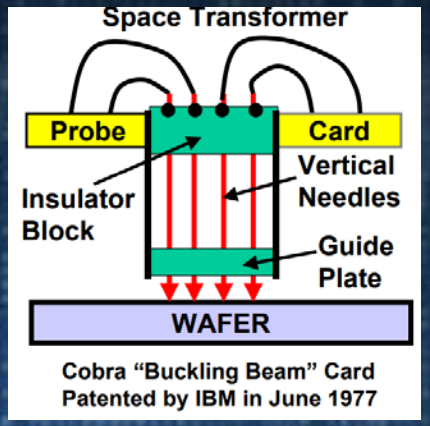


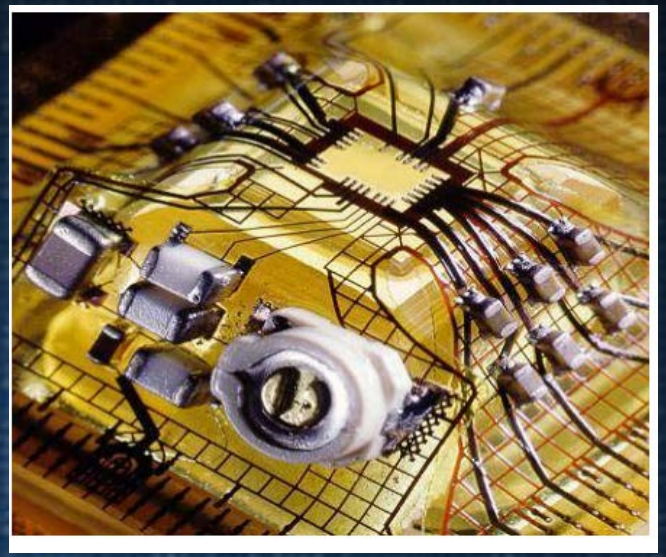
DUT Interface

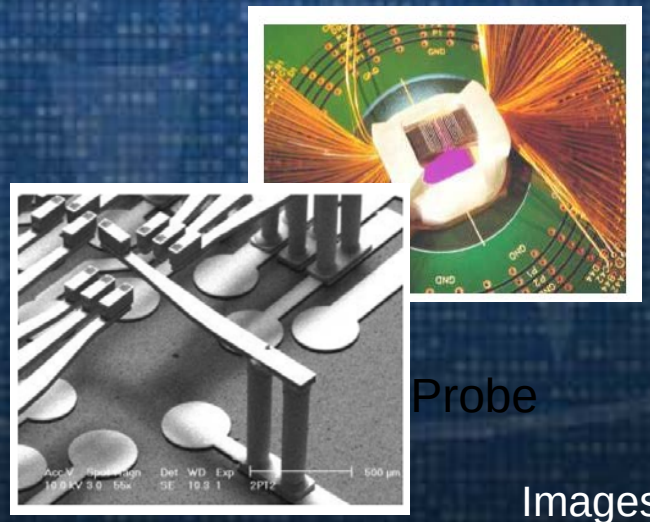


Current RF Probe Limitations

- **Cantilever**
  - No impedance control
  - Extremely High inductance
  - Limited to <2GHz
  - Decoupling components far from DUT
- **Vertical Probe**
  - Shorter uncontrolled impedance path
  - Lower inductance than cantilever
  - Limited to <6GHz
  - Decoupling components ~1-2cm from DUT
  - Individually replaceable probes
- **Membrane**
  - Impedance controlled to DUT
  - No additional inductance
  - Decoupling caps ~1-5mm from DUT
  - Limited compliance (~50um)
  - Fragile
  - Not field replaceable







Probe

Images provided by William Mann Chair, Southwest Test Workshop

xWave: Wafer Level Final Test

Shortest signal path from die to tester

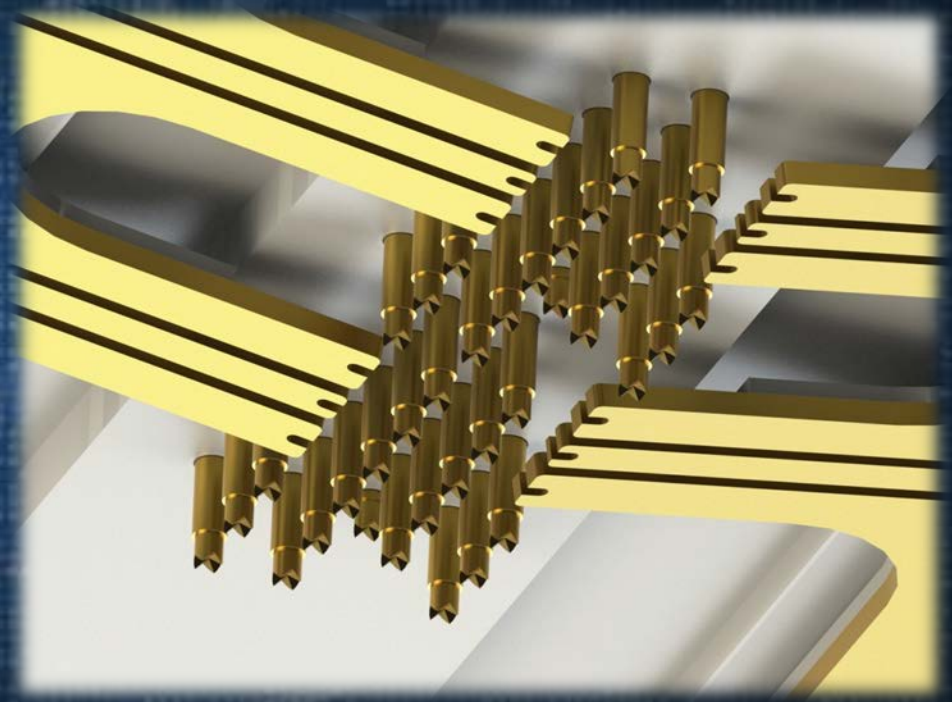
- Direct Tester to DUT connection
- High speed signals bypass PCB
- Impedance controlled signal path

Same core technology as standard xWave

- Robust Leadframe technology
- Hybrid Pogos for Power and control signals

Made for Production Environments

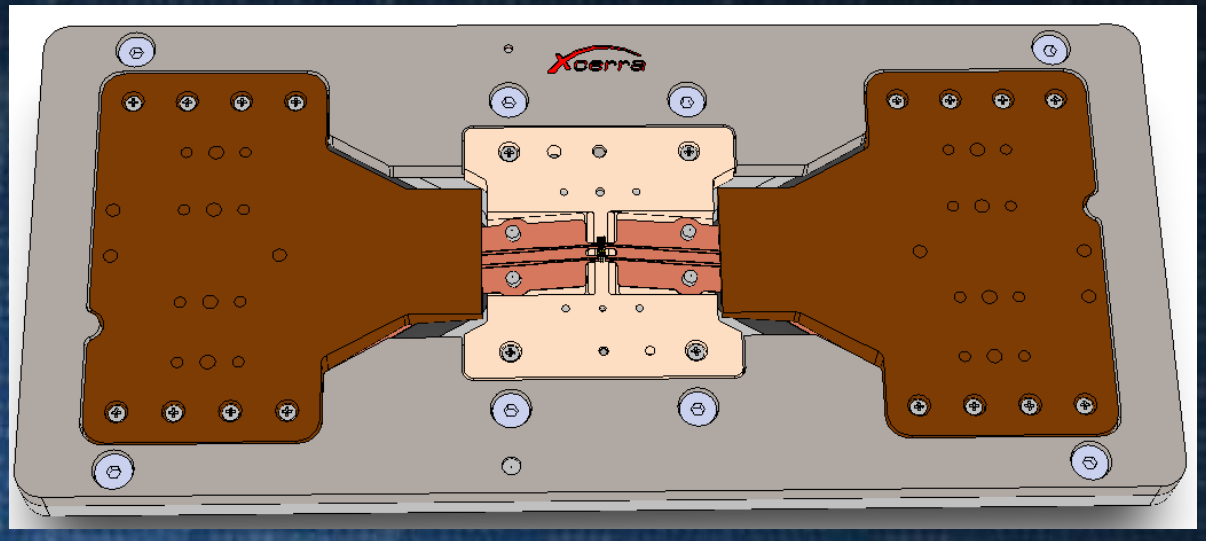
- *Field replacable spring probes, leadframes, connectors/waveguides*
- 200um overdrive

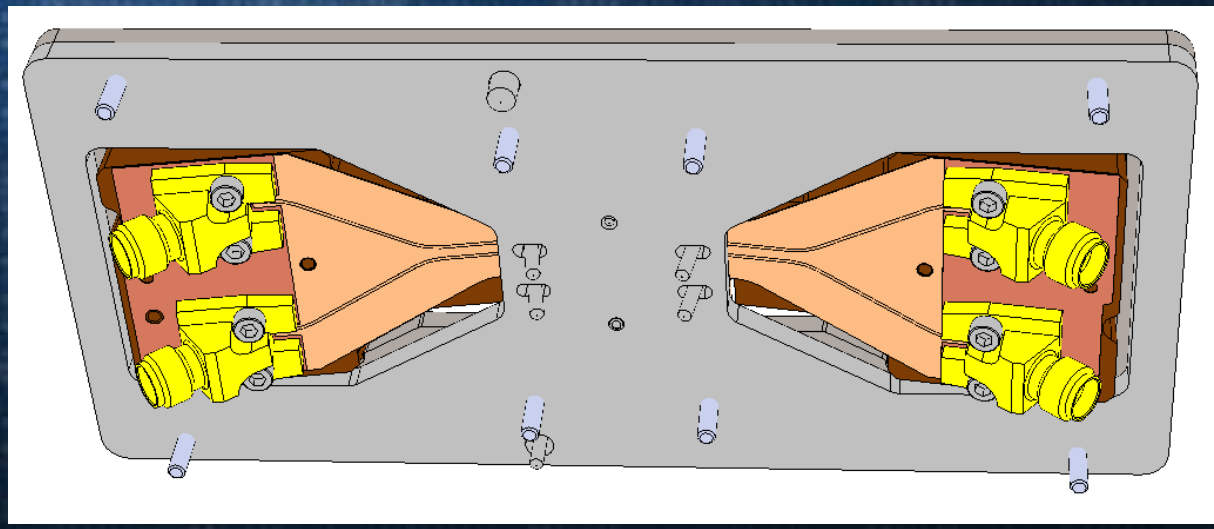


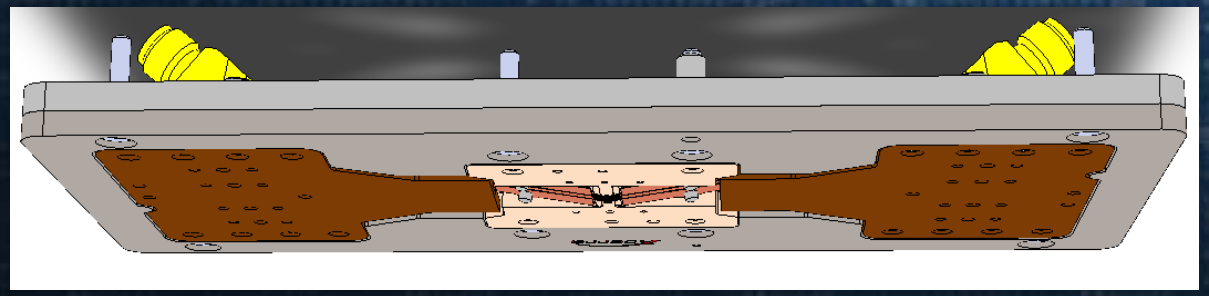
Wafer level probe solution up to 100GHz and pitches down to 100um

WLCSP xWave Design Goals

- **Maintain as much as possible from package test xWave technology**
  - mmWave Signal integrity
  - High compliance
  - Field maintainability
  - Robustness and longevity
  - Tri-Temp capability

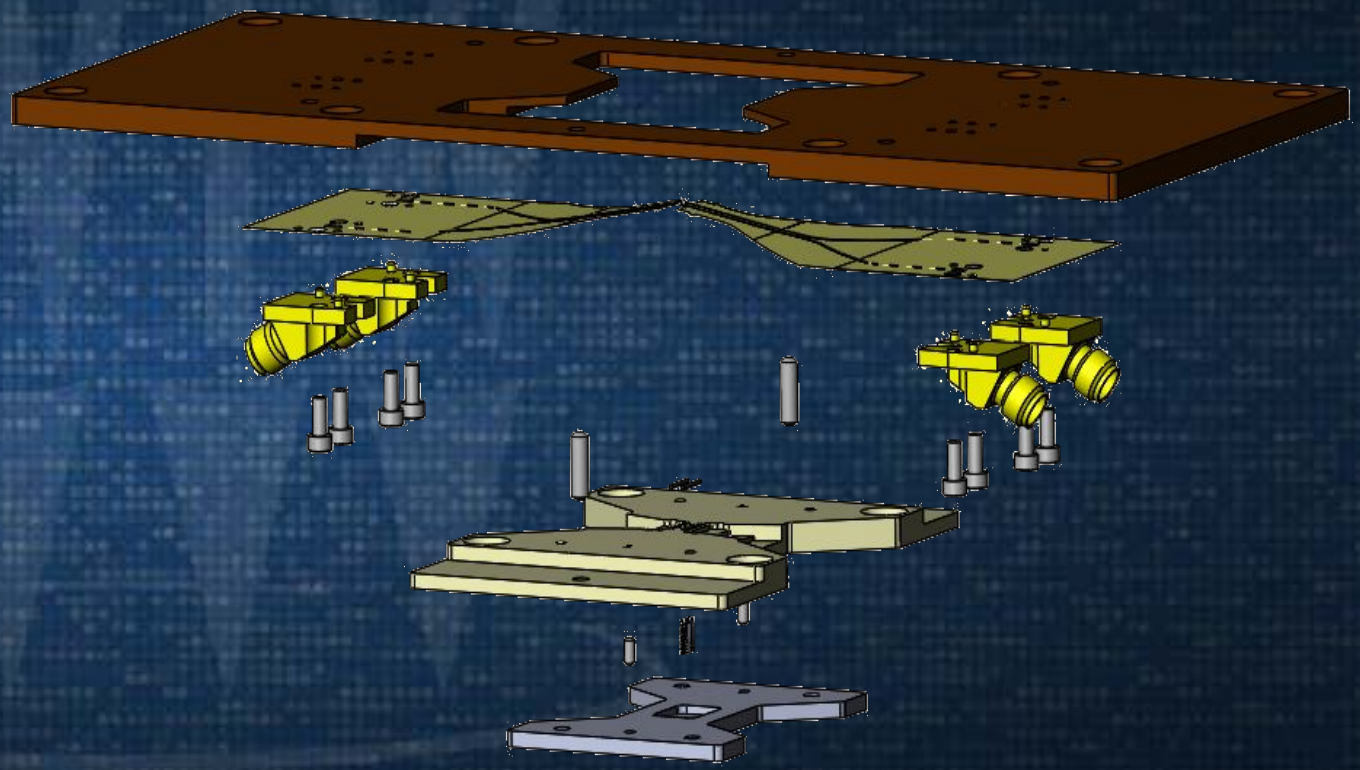






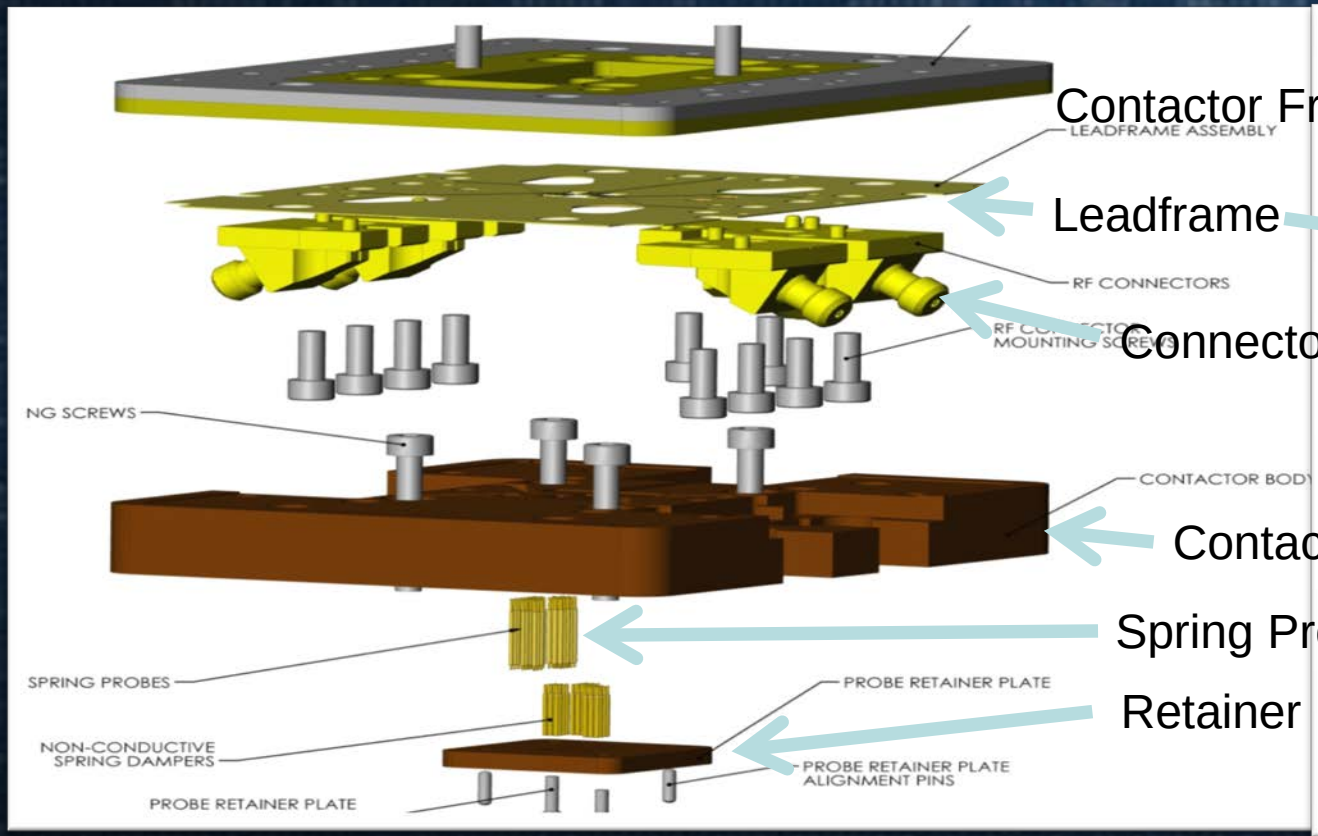
Objectives/Goals

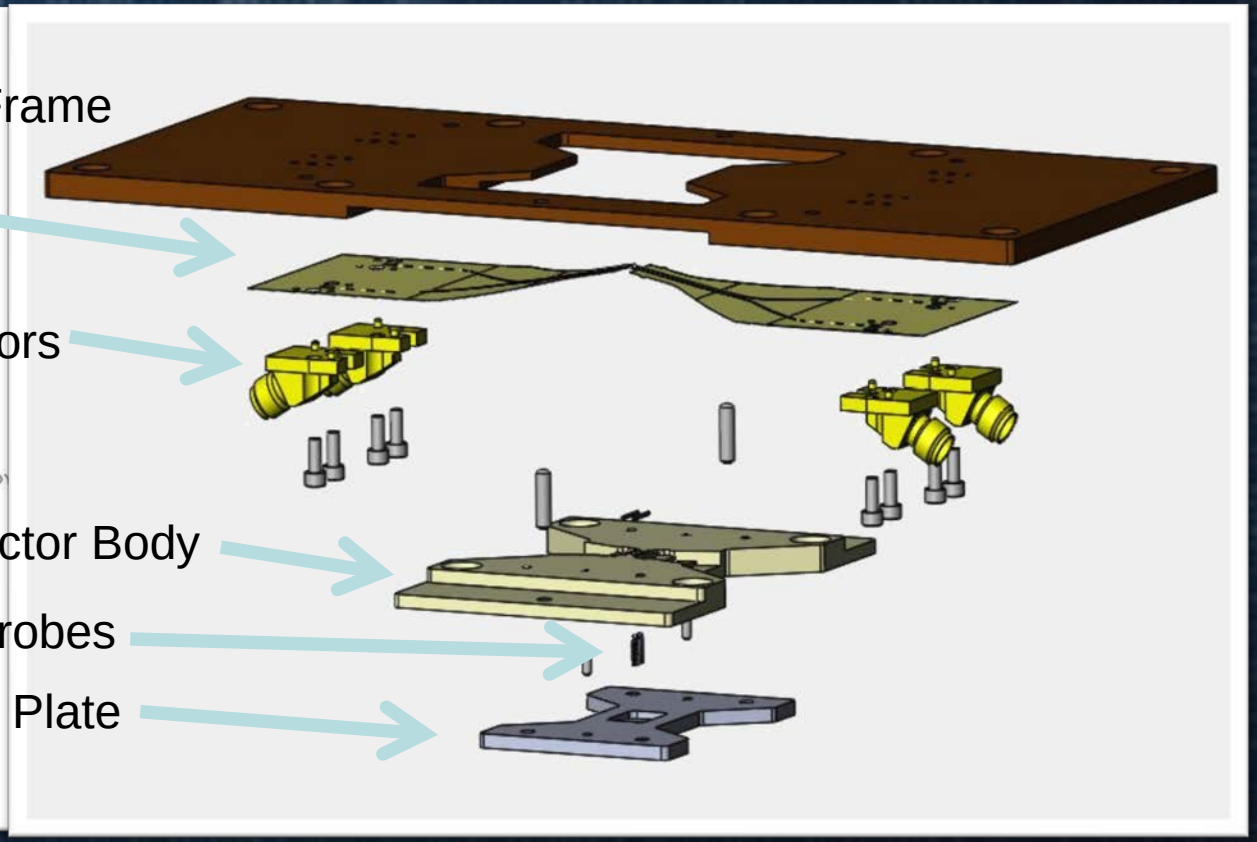
- **Move xWave Technology from package test to wafer probe**
  - Move contact point of leadframe to infinite plane
  - Combine leadframe with fine pitch pogo technology
  - Reduce leadframe features to match bump pitch
  - Reduce leadframe force to limit contact marking on wafer bumps
  - Limit scrub to ensure no ball shear



Package Test vs. Wafer Level Test xWave Comparison

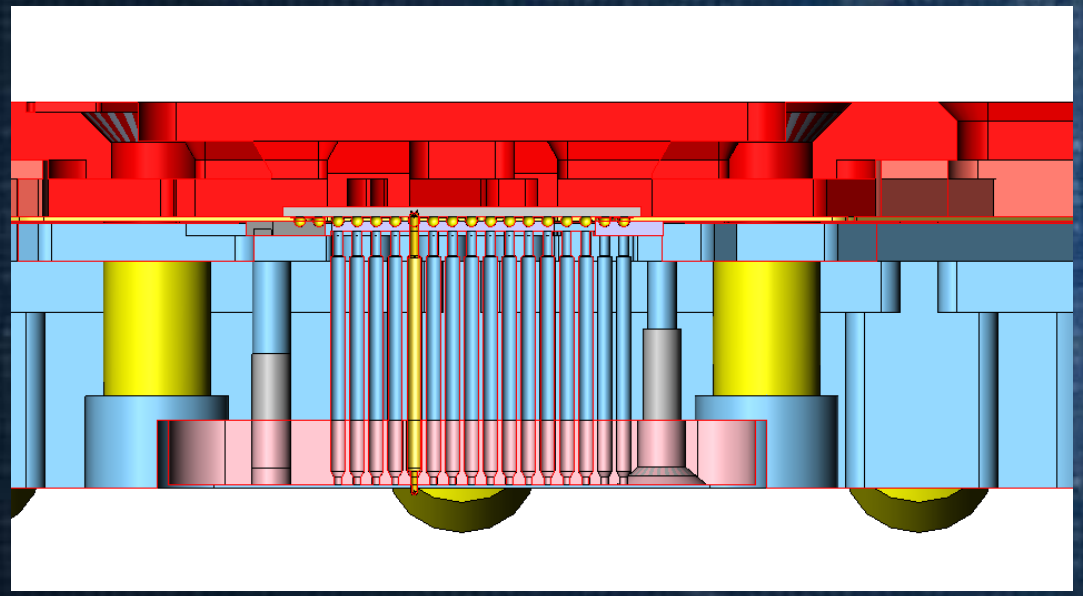
- **Package Test xWave**
- **WLCSP test xWave**

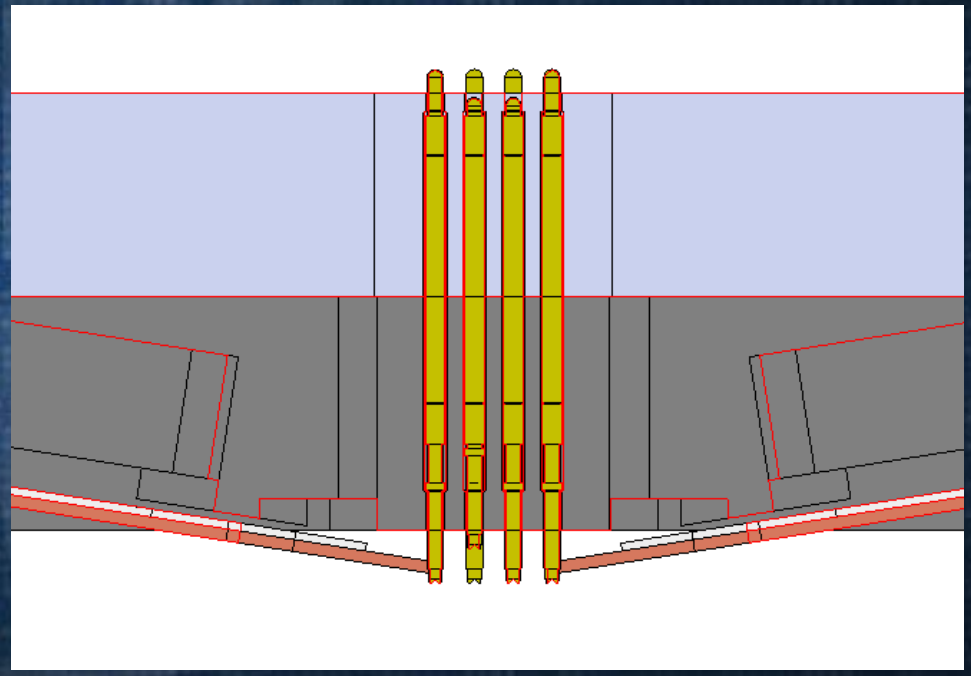




Move contact plane to infinite plane

- From Flat leadframe in DUT pocket to Angled leadframe at infinite plane





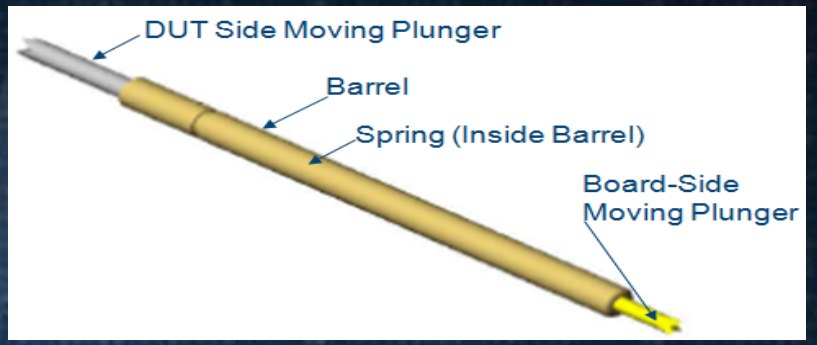
- From CSP5 probe to CSP015 probe

CSP Family of High Performance Tough Probes

Designed for Rugged High Performance

High Reliability, corrects connection between uneven surfaces and satisfies high throughput in mechanically demanding high volume test applications

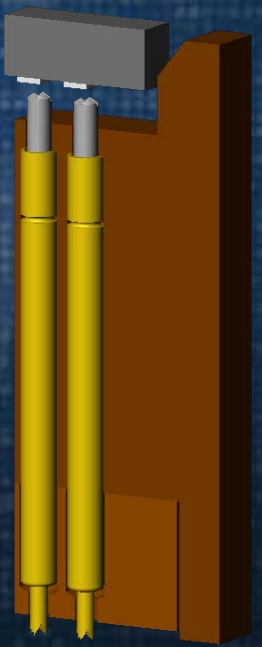
- Increased durability for heavy duty applications
- Highly customizable size, stroke, and pin count
  - Uneven mating surfaces
  - High tolerance stack-ups
- Easily Integrated
- High current/power device test



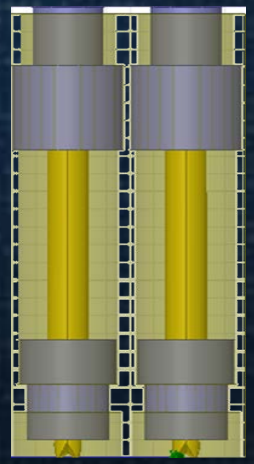
Large compliance window ensures consistent contact

- Large compliance window compensates for less-than-perfect device co-planarity
- Reduced or eliminated false failures due to package warp, interface board bowing, etc

CSP Singulated and Strip Test



ICON - CSP Coaxial

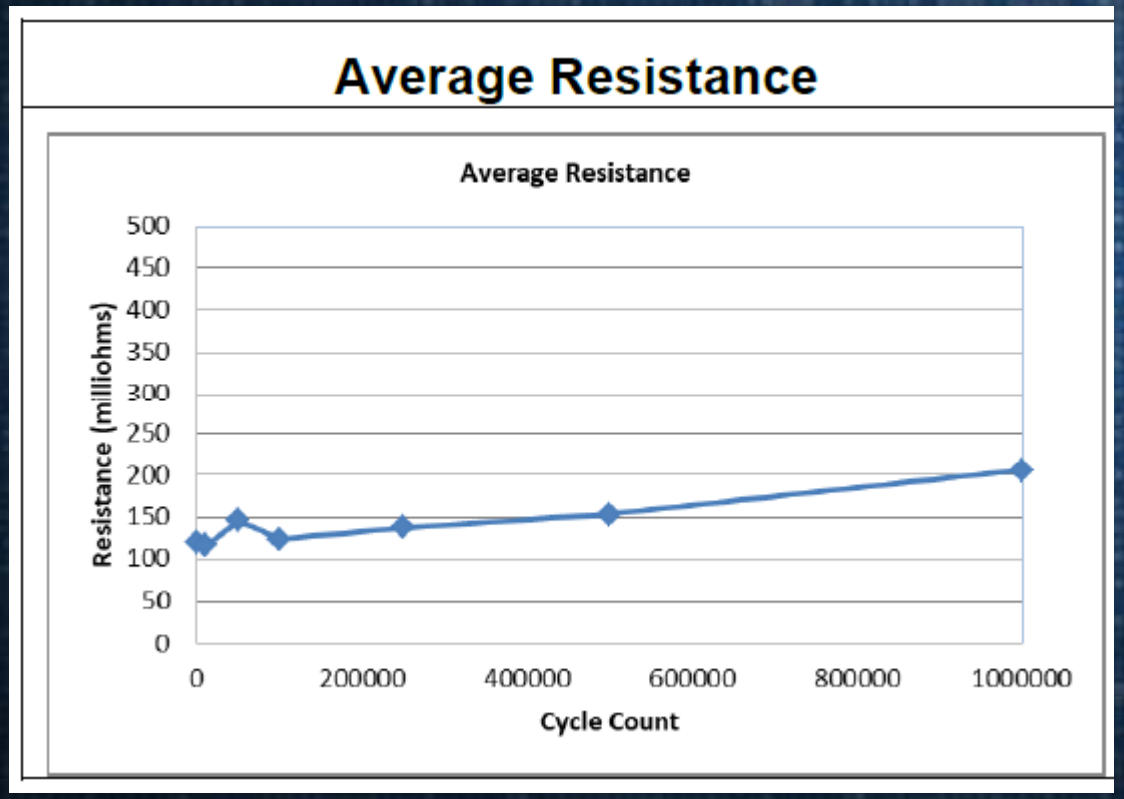


One probe test floor standard

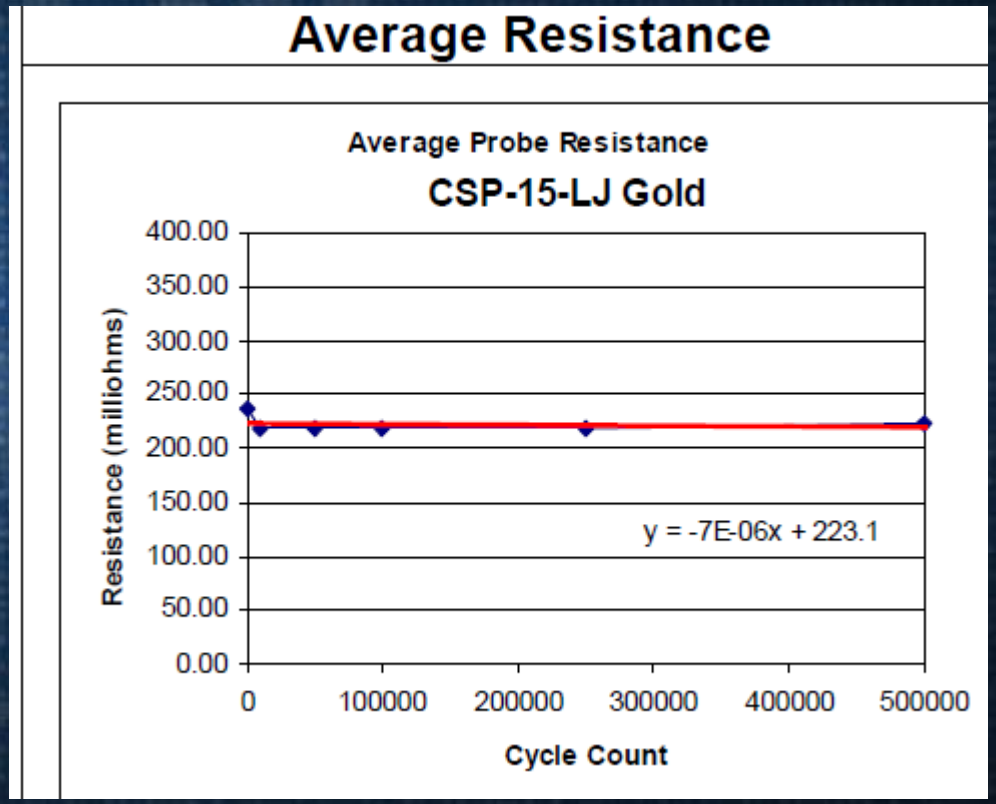
- 0.15 mm, 0.4 mm, 0.5 mm and 0.8 mm pitch

Probe comparison

- CSP5

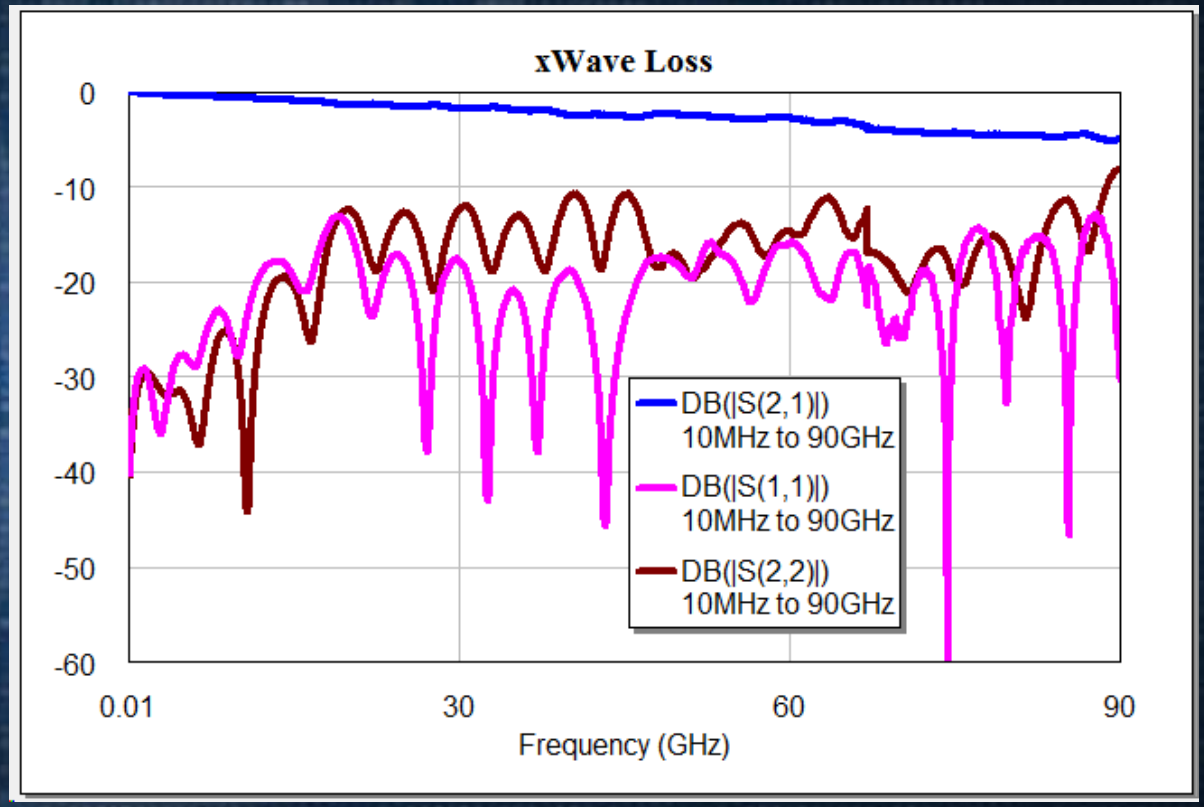


CSP015



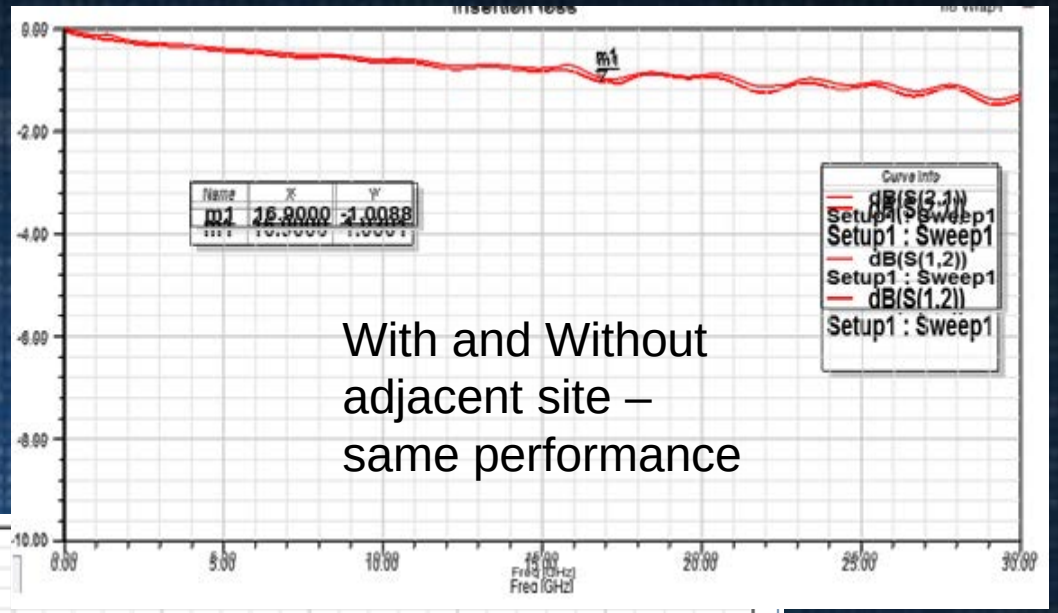
WLCSP xWave Signal Integrity

- **Same Coplanar Waveguide Leadframe structure as package test version except:**
  - Thinner metal
  - Finer pitch
  - Narrower RF leads
  - Smaller ground signal gap
  - Adjacent site solder ball proximity
  - With and without ground wrap

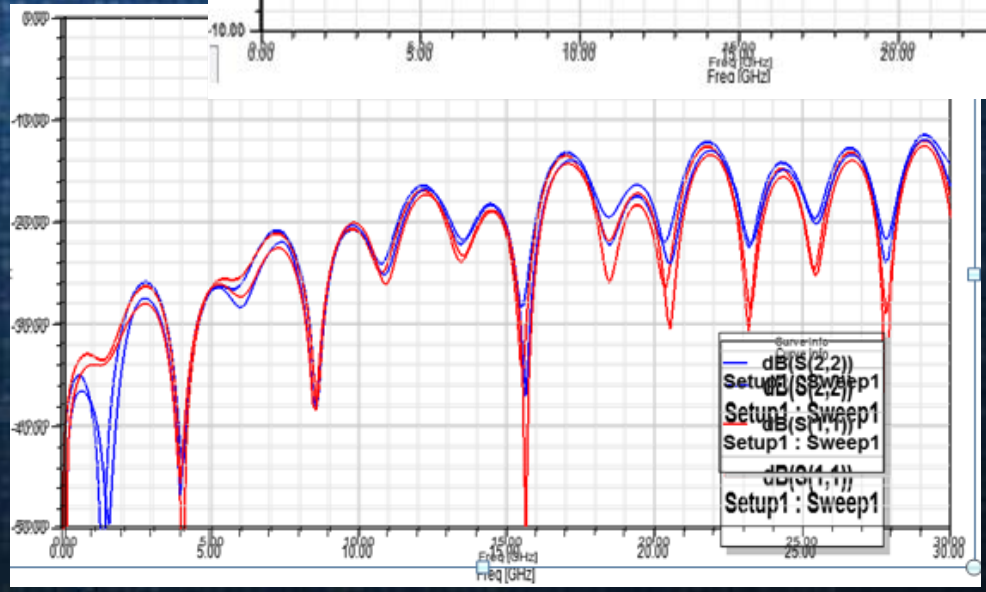


WLCSP xWave Signal Integrity

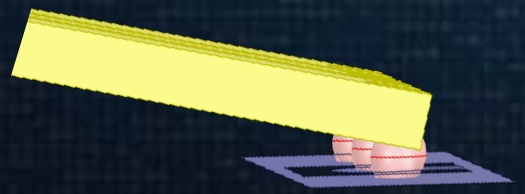
- **Impact of Adjacent site**
  - 15deg angle at free height
  - 5deg angle at test height
  - Proximity of adjacent site to test site
  - Same performance with and without adjacent site



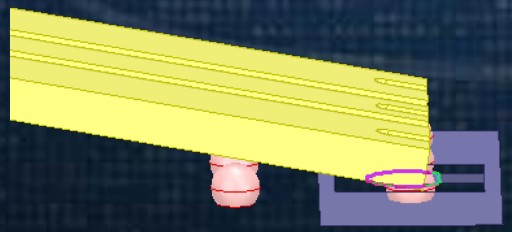
With and Without adjacent site – same performance



No adjacent site

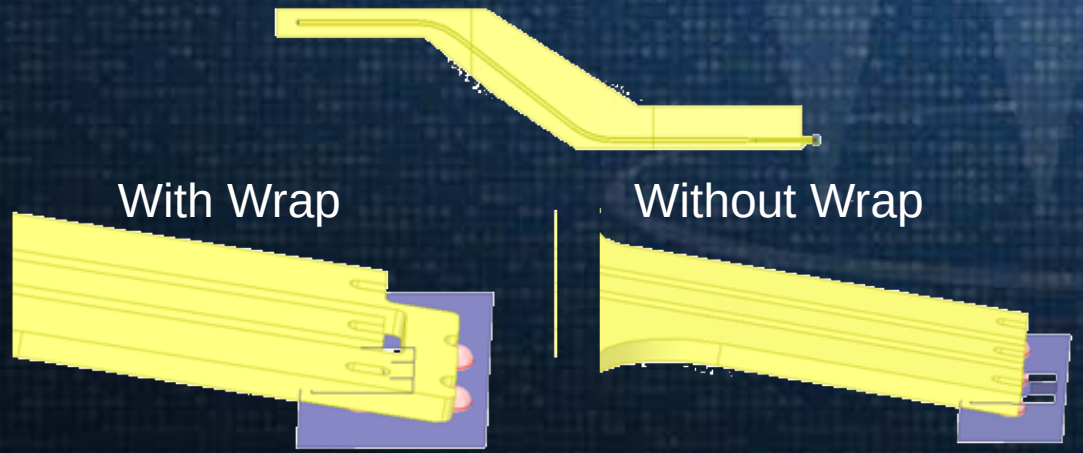


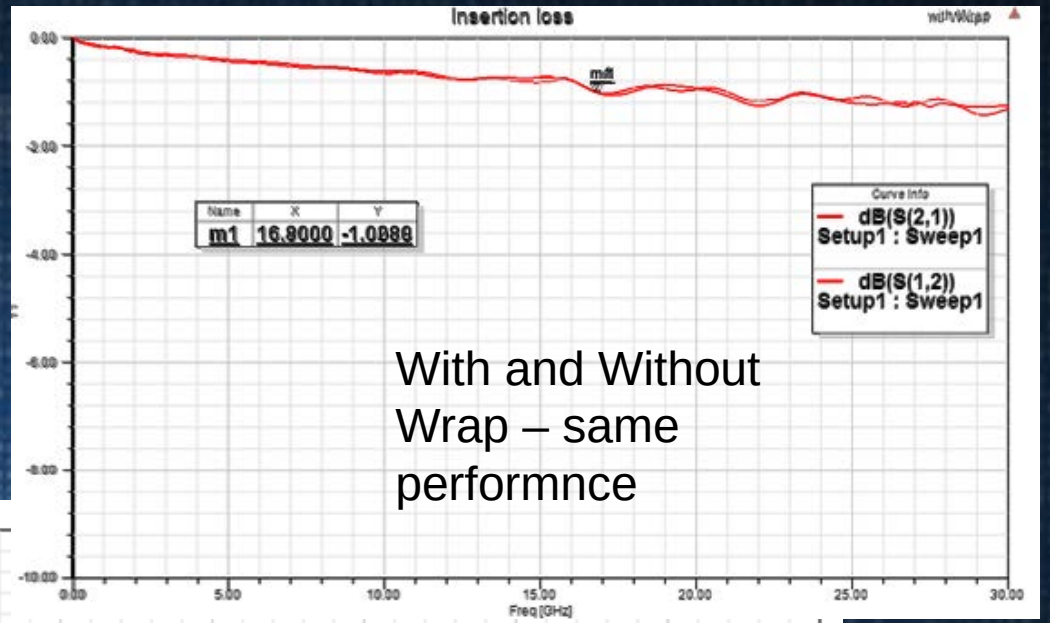
with adjacent site



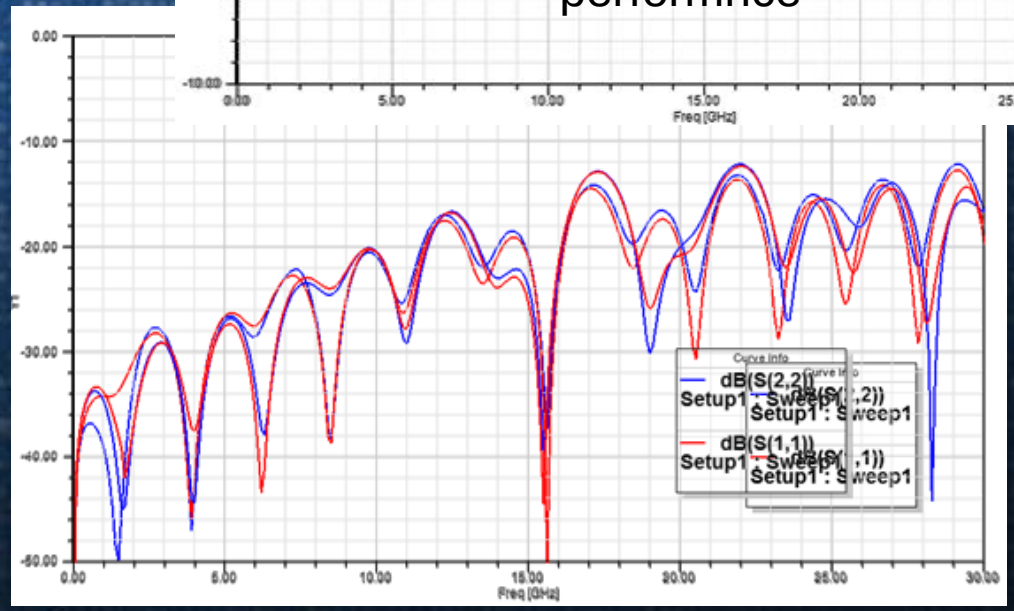
WLCSP xWave Signal Integrity

- **Eliminated CPW ground wrap**
  - Relies on DUT to maintain ground potential on either side of signal lead
  - Same performance with and without ground wrap

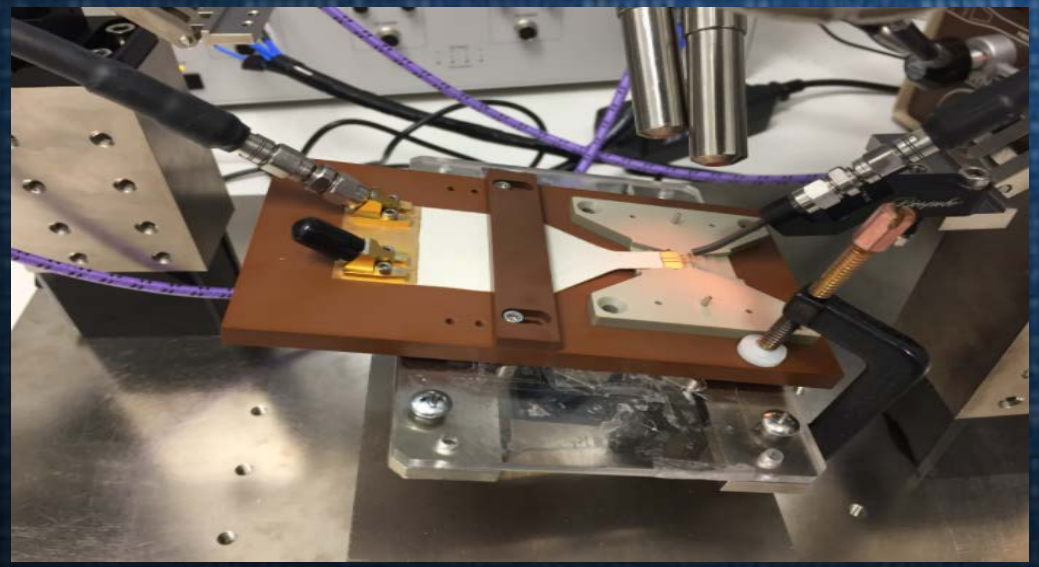


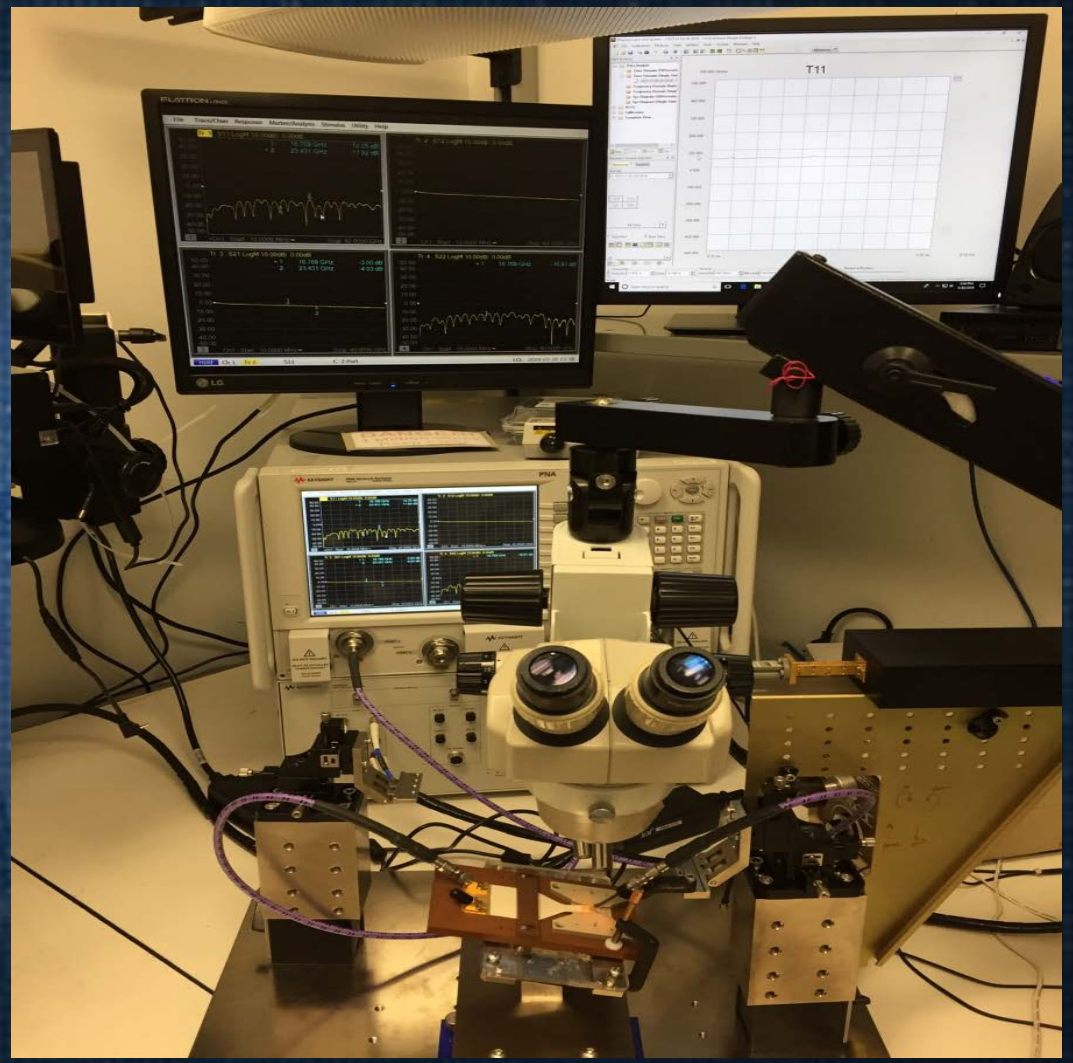


With and Without Wrap – same performnce



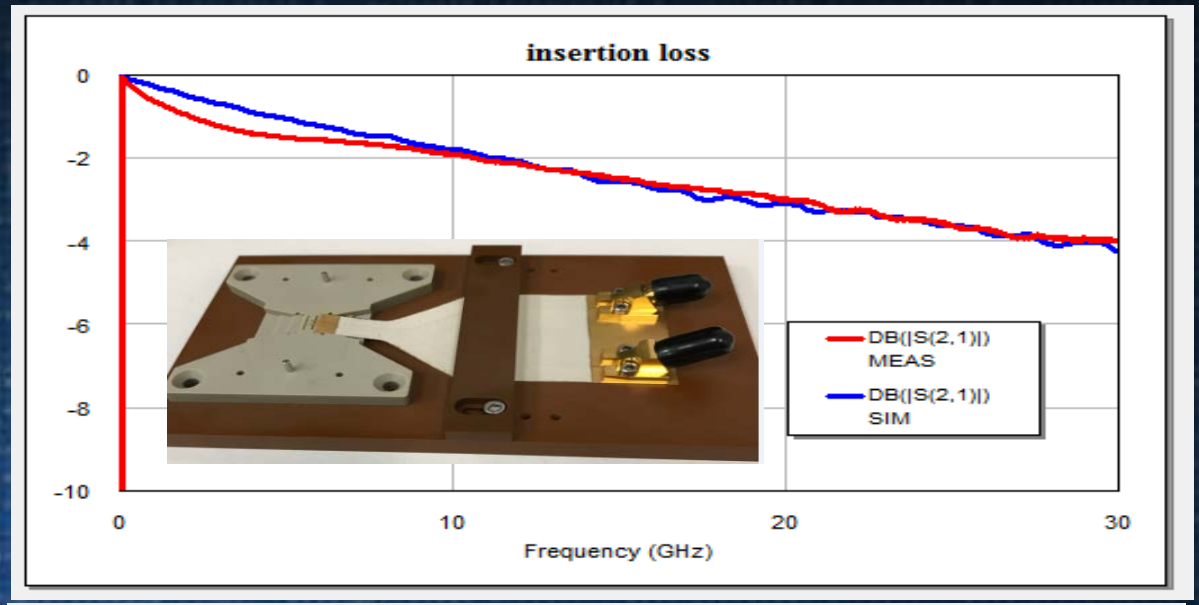
xWave Dual Site Probe Card Prototype RF Lab Measurement

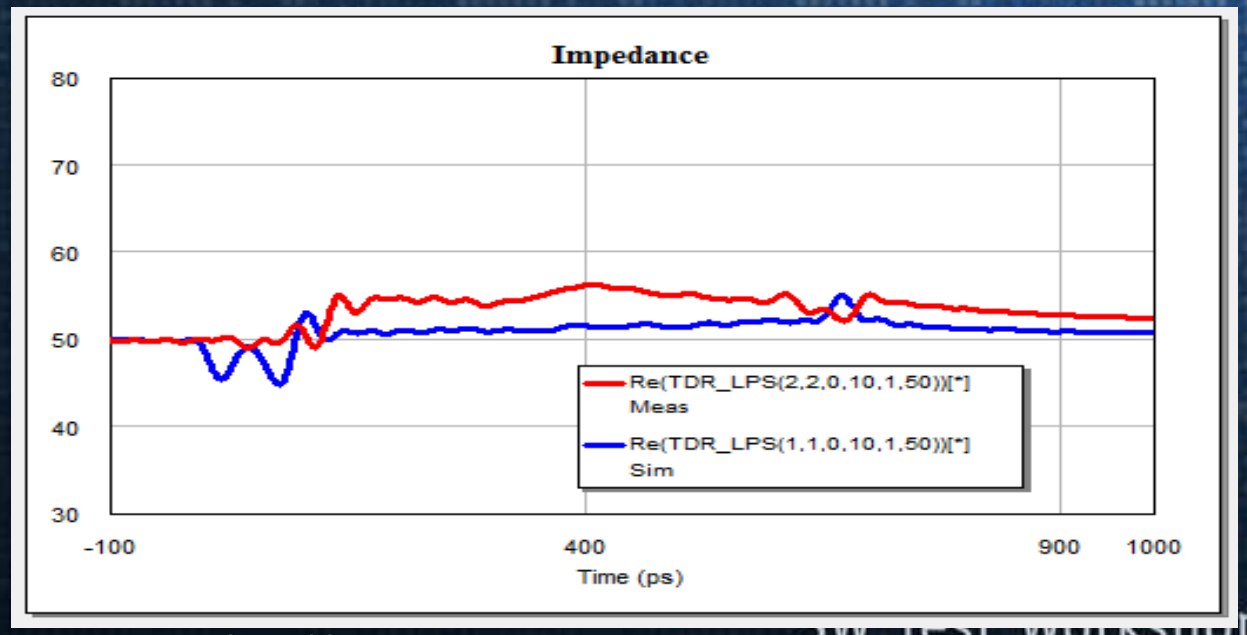


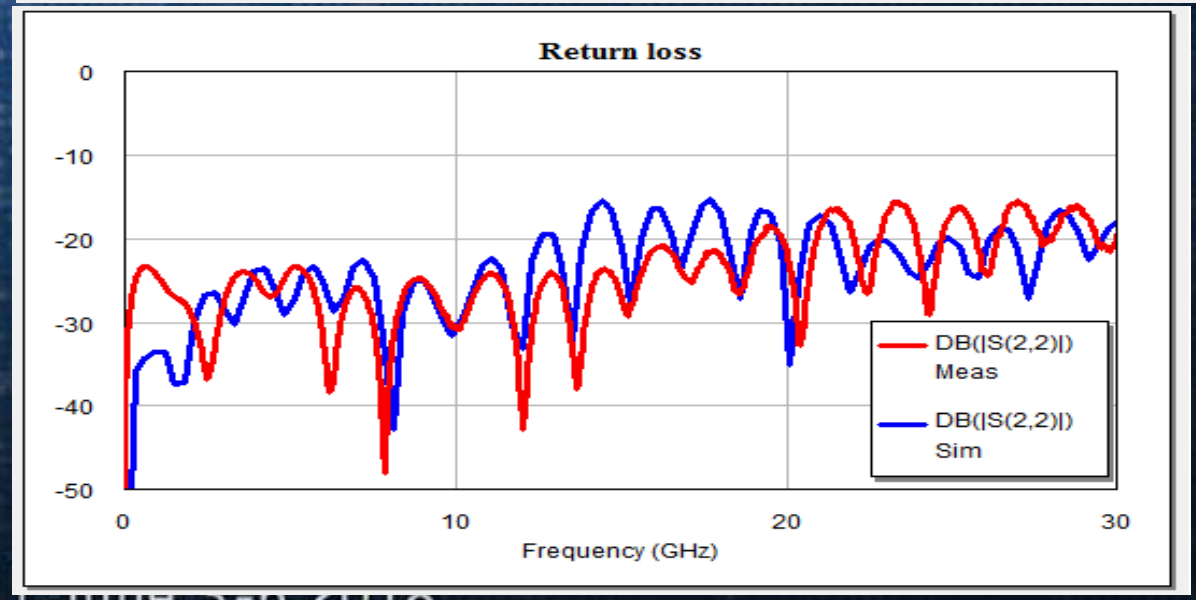


Simulation – xWave Dual-Site Probehead

- Linear Insertion loss linear through 40 GHz
- Return loss less than 15dB
- Impedance Matched within 10%
- Application optimized for 30GHz max frequency
- Technology applicable to 80GHz

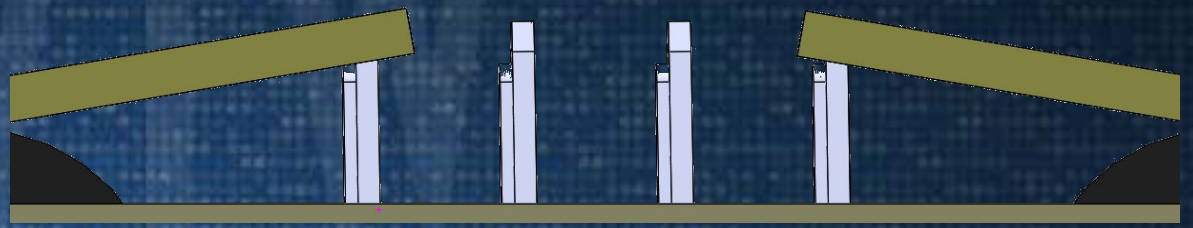


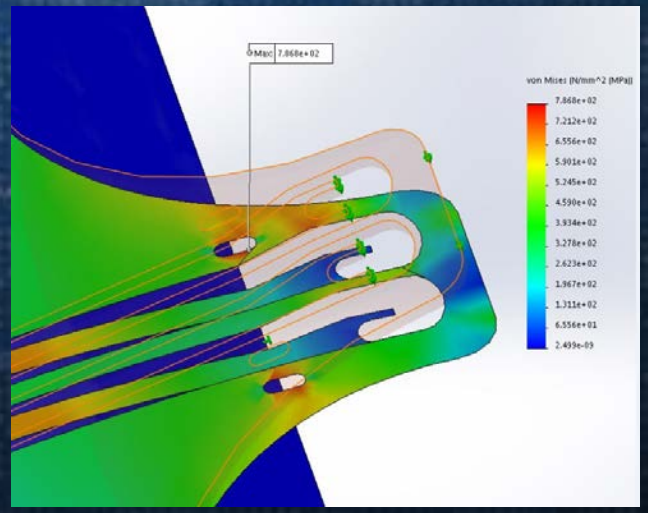




WLCSP xWave Mechanical Design

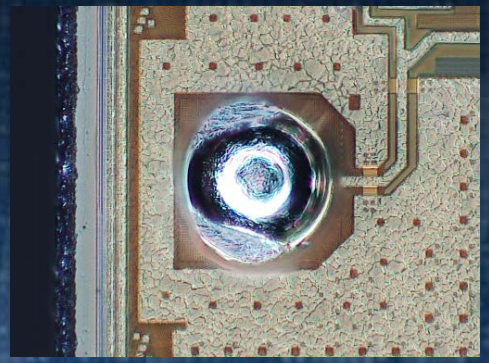
- **Force**
  - Leadframe – 14g @ 150um overtravel
  - Adjustable based on leadframe cross section and cantilever anchor
  - Sufficient force without spring damper
- **Thermal**
  - Designed for Tri-Temp
  - Same materials as standard xWave
  - All materials match CTE

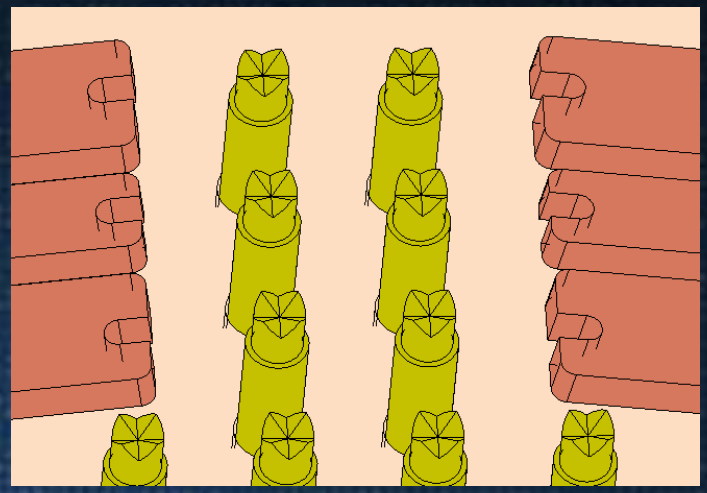


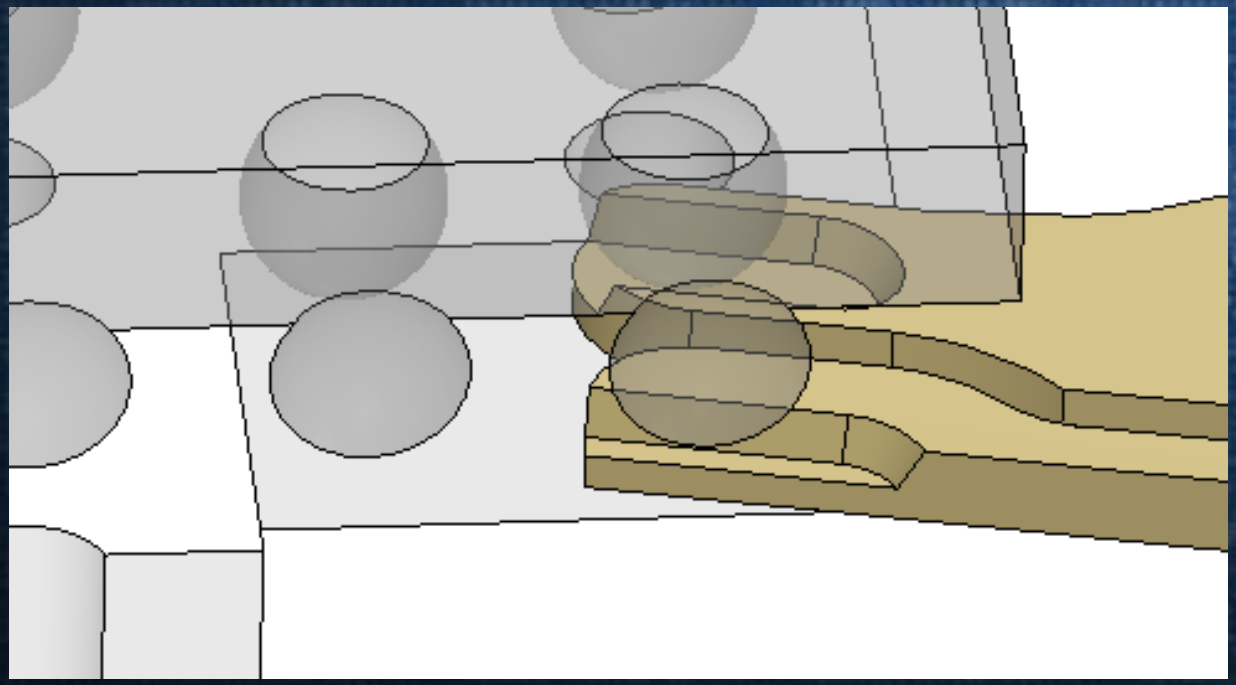


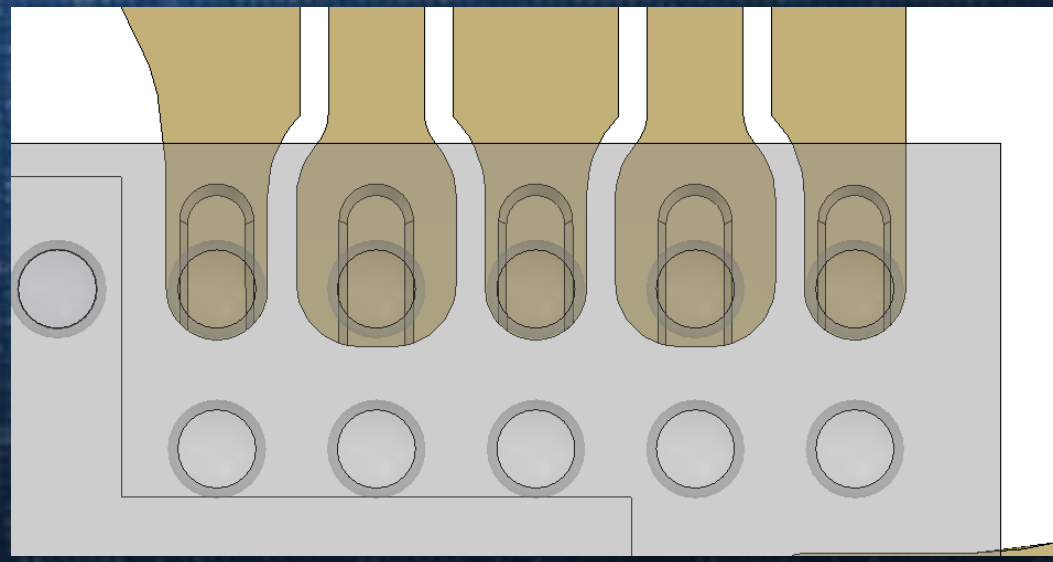
WLCSP xWave Mechanical Design

- **BGA Contact feature**
  - Leadframe - U shape edge contact to ball
  - ~10um knife edge scrub
  - Pogo – 4 point crown



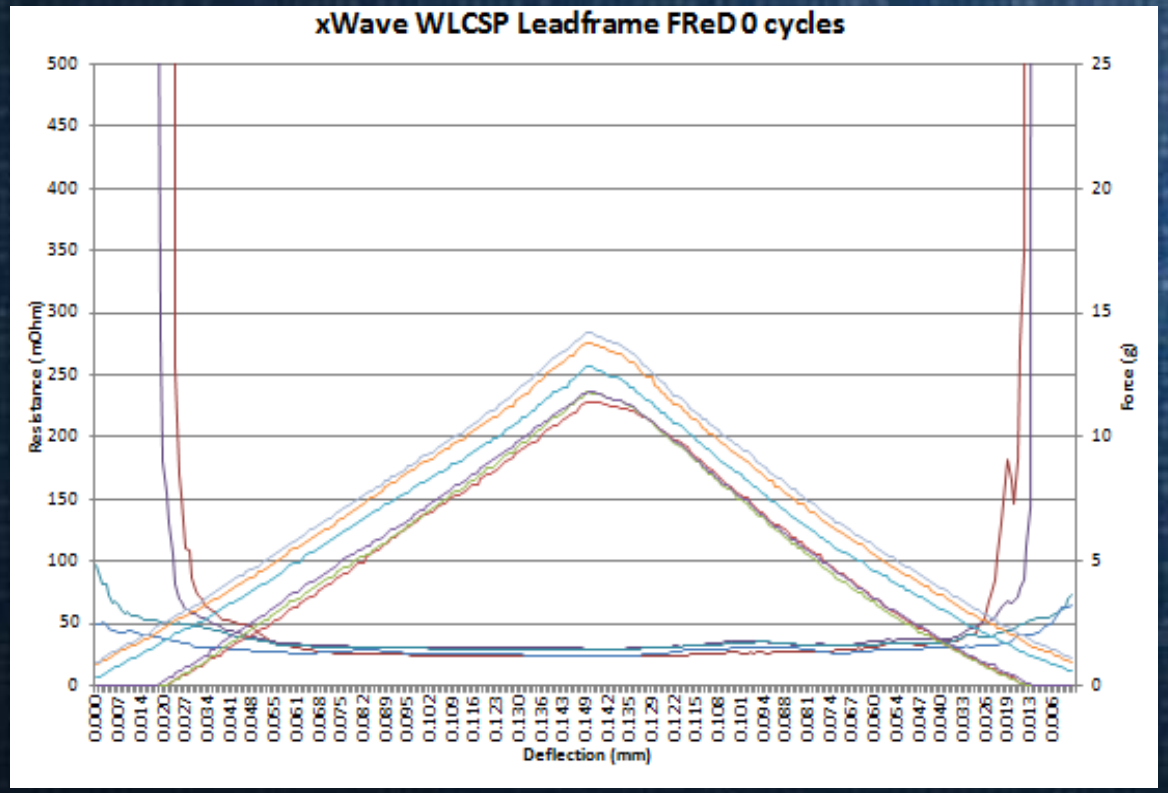


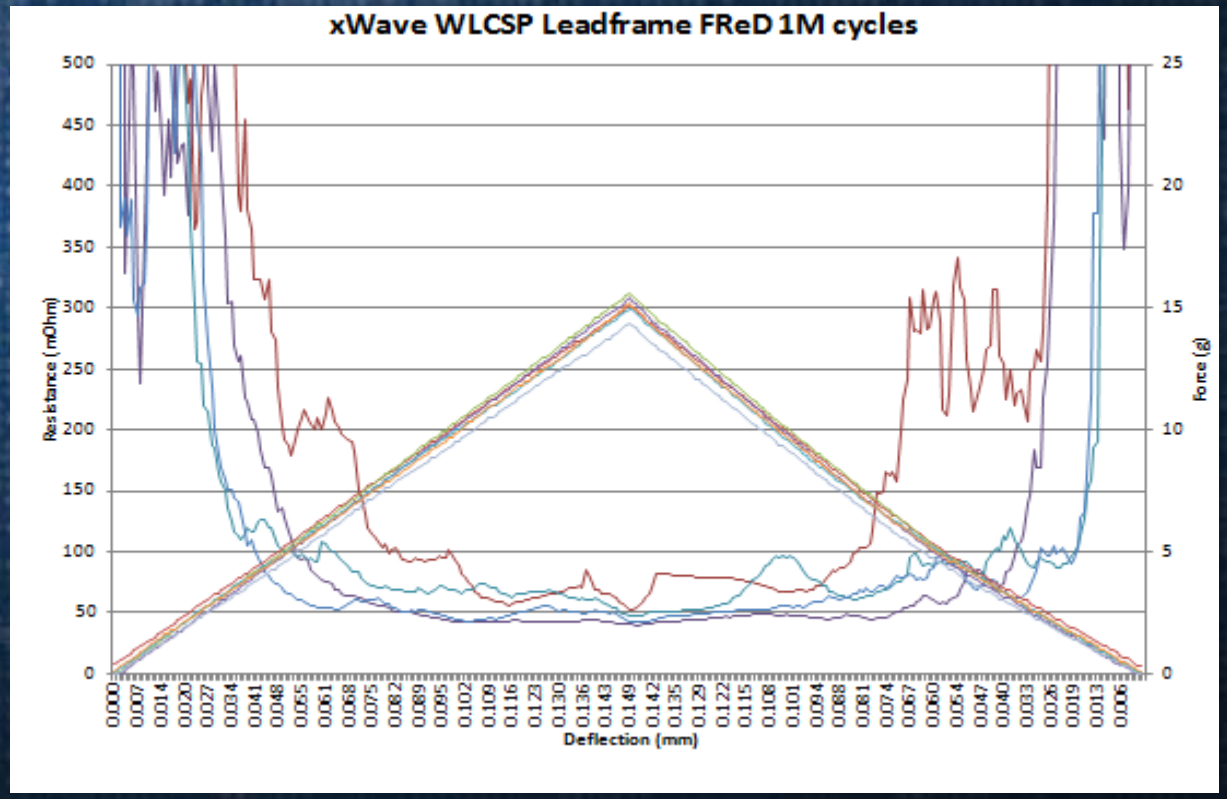




WLCSP xWave Life Cycle

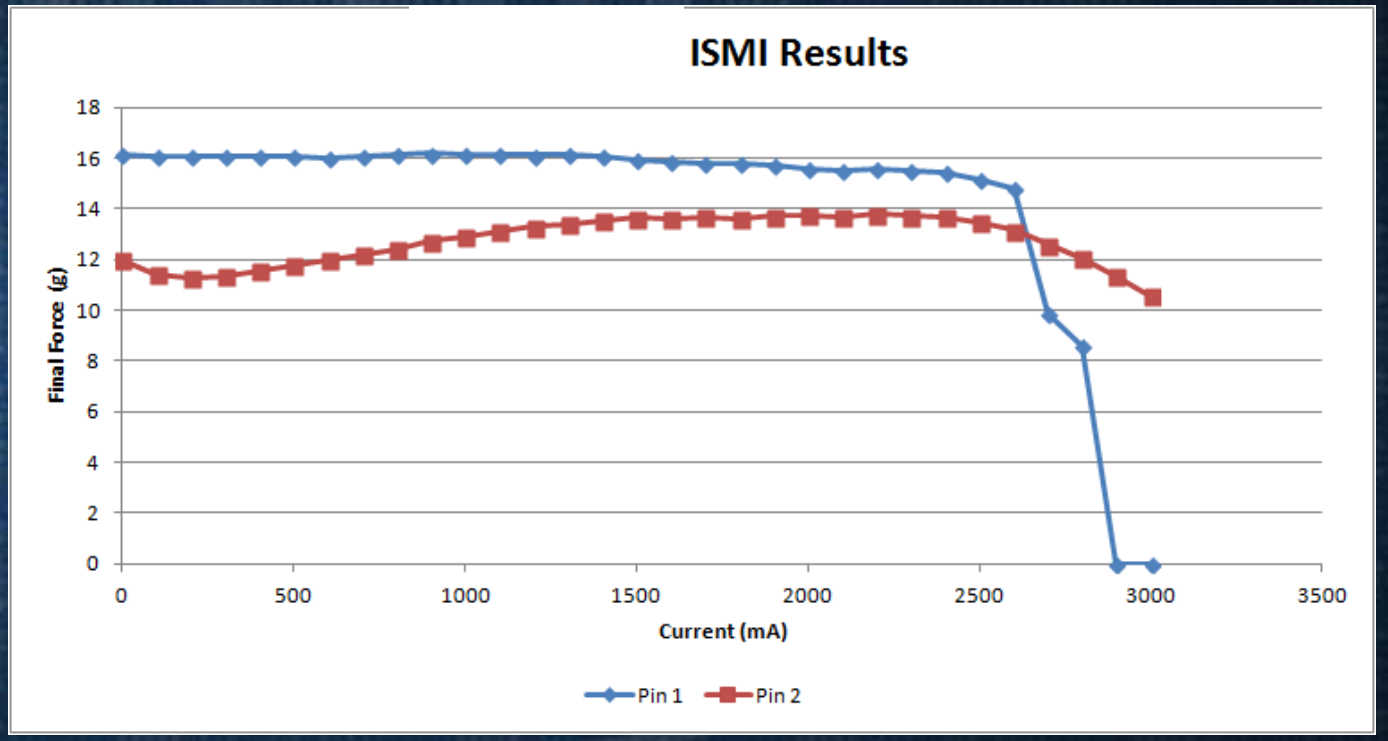
- Stable low contact resistance through 1M cycles
- No force degredation over 1M cycles





WLCSP xWave DC Performance

- **Current Carrying Capacity**
  - 2.6A based on ISMI method
  - Limited testing
  - Pressure applied to signal lead only
  - Expect higher current carrying capacity when deflecting grounds and signals



Package Test and Wafer Test in 1

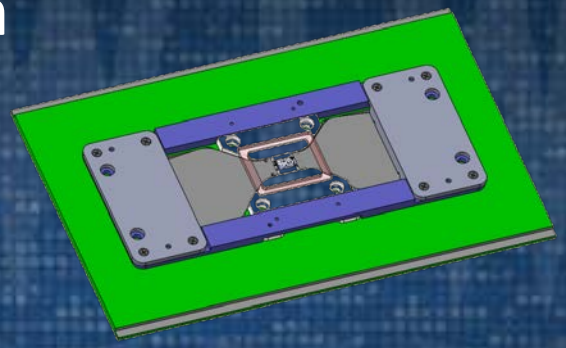
- **Same hardware can be used for both packaged test and wafer test**
  - Manual Alignment Frame (MAF) attaches to Probe head to convert to final test
  - Manual Actuator (MA) attaches to MAF
  - Simple change over from Wafer to Packaged parts for QA or RMA's

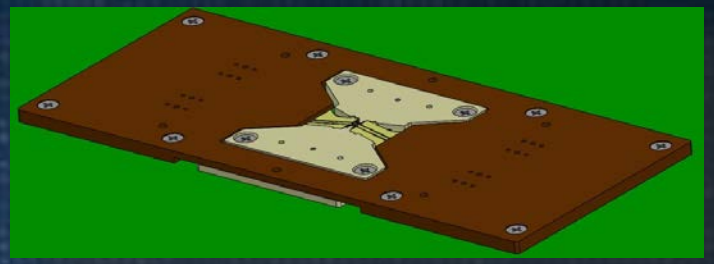
Summary/Conclusion

- 5G, ADAS, Wireless, Satellite cmWave and mmWave markets growing rapidly and moving from package to WLCSP at speed
- WLCSP xWave is based on the same technology that's proven in the field to 1.5M cycles and going
- Overcame infinite plane and force profile to take the xWave technology from final test applications to wafer test.
- Optimized signal path for the best signal integrity
- Test data shows similar excellent performance expected from Wafer Level version of xWave

Follow on work

- **2 ongoing Beta sites**
  - Dual site 16 lead 250um pitch Ku/Ka band (12-40GHz)
  - Single site 150 lead 180um pitch 5G (28GHz)





Item	January					February				March				April				May				June			
	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25
Probe Card Design / Build / Test Tasks																									
Initial Probehead Design																									
Prototype Probehead Build / Manufacturing																									
Prototype RF Testing																									
Prototype Mechanical Testing																									
Receive PO for Probe Card (Probehead FOC)																									
PCB Design / Build (PCB Vendor)																									
Optimize Beta Probehead Design																									
Approve Beta Probehead Design																									
Beta Probehead Build/ Manufacturing																									
Beta Probehead RF + Mechanical Verification																									
Beta Probe Card Assembly																									
Beta Probe Card Delivery																									