SWTW 2-0-1-8

SW Test Workshop

Semiconductor Wafer Test Workshop

New Approach in Pogo Socket Design to Improve Total Cost of Ownership

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Agenda

- Introduction
- Objectives
- Approach and Lessons Learned
- New Applications
- Summary
- Follow on Work

Introduction

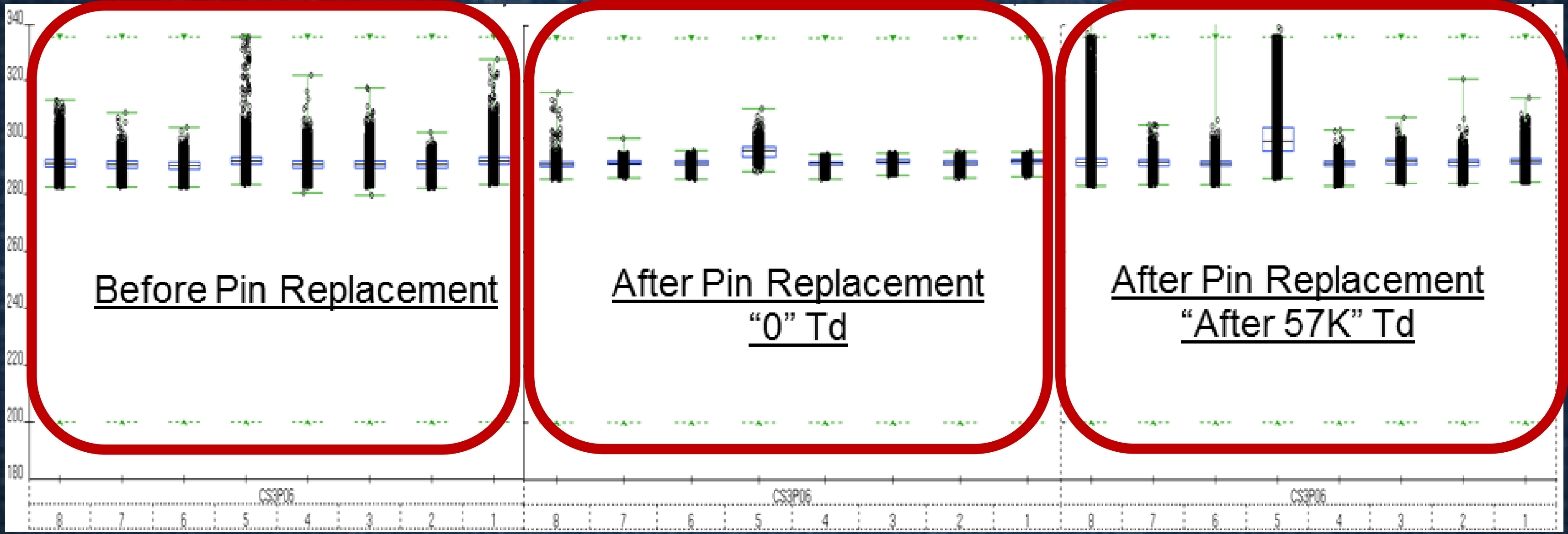
- Wafer Socket Probe (WSP), or pogo pin probe card, is low-cost, easy to maintain, and pins can be replaced 100% in-house. It is the roadmap technology for probing WCSP or bump wafers in TI. The number of pogo pin probe cards has increased significantly in the last 7 years. However, this probecard technology have several challenges on performance in the production line.
- Frustrations on day to day Stability that's impacting output and tester utilization, Cost, and Quality. As factories aim for low-cost and efficient operation, we need to challenge the status quo. We need to change the mind-set and expectations.
- This paper will review the qualifications to bring the performance to the next level to improve Total Cost Of Ownership validated through high volume manufacturing. And how we leverage these benefits to other applications like flip chip, copper pillar, copper pads, and potentially on Aluminum pads.

Objective

- **Stability Improvement**
  - Downtime due to striping failures
  - Low yield and high re-probe rates
  - Low tester OEE and long output cycle time due to stoppage during production
- **Cost Reduction**
  - Replacement of pogo pins on as low as 150,000 touchdowns
  - Increased spare level to cover the capacity loss
- **Quality Risk Elimination**
  - Damage wafer bump due to protruding screw on the probe head.
  - Rework and scrappage of affected wafers

Overview

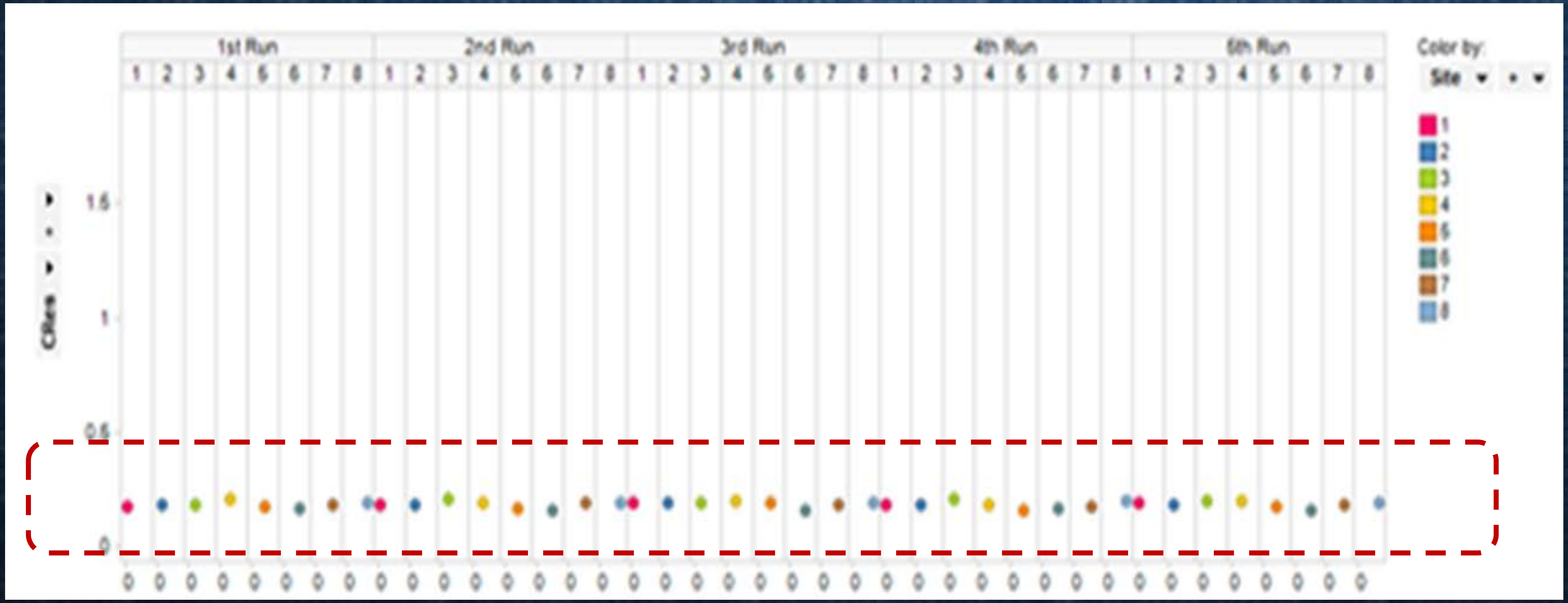
- **Stability – Normally, we "Replace" pogo pins when we encounter problems related to probehead.**



  - Site to site distribution of device with test failures.
  - 100% pin replacement to resolved Site-to-site failure.
  - Failures were observed again at 57k touchdowns. Problem not solved.

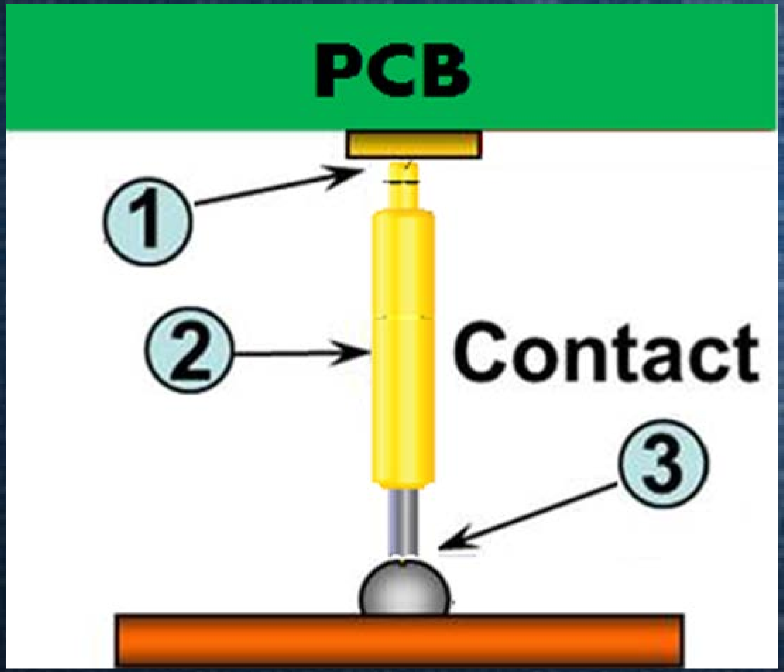
Bulk Resistance

- **Verification of pogo pin CRES (Bulk Resistance)**
  - Using pogo CRES checker, the CRES across all sites are the same.
  - Meaning, the CRES related failures were not Pogo Pin related.
  - Meaning, we were just wasting $$$



Total CRES

- **Stability – Contact Resistance (CRES)**
  - The sum of all the resistances associated with interfaces and the bulk resistance of a contact.
  - The "Contact Resistance" of a contact is shown in the schematic below and includes:

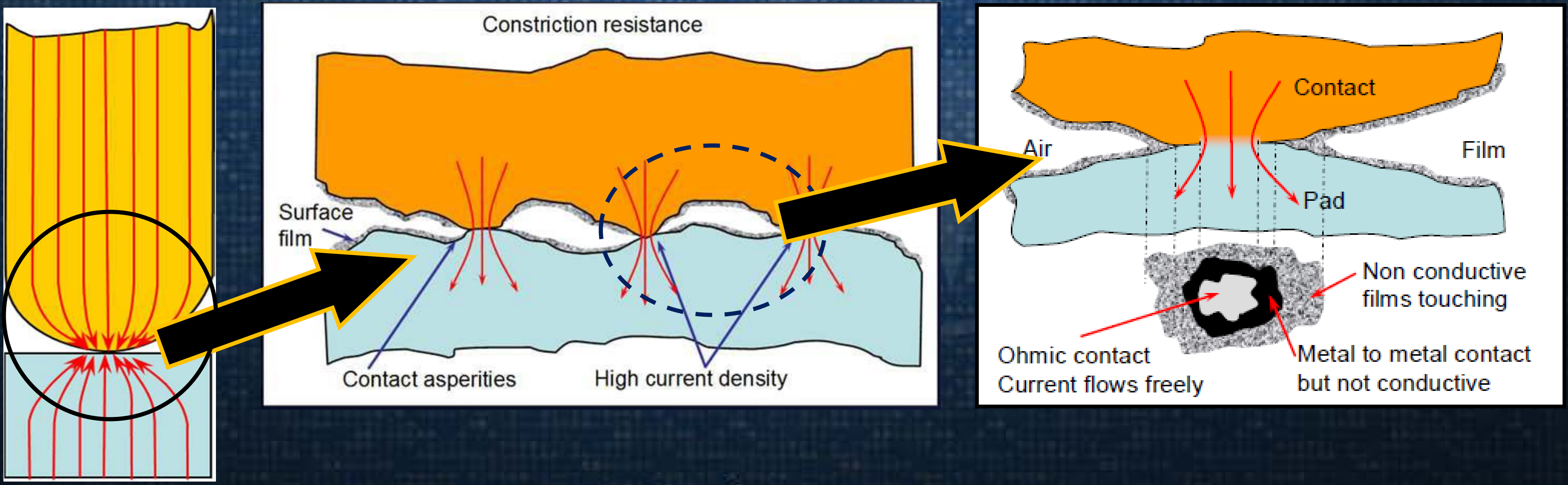


1. The "*constriction resistance*" of the pad on the test board (PCB) and the contact (Pogo pin)
2. The bulk resistance of the contact.
3. The "*constriction resistance*" of the interface between the solder ball and the contact.

The Other CRES

- **The Constriction Resistance**
  - While the bulk resistance of the contact is purely the CRES of the pogo pin, the Constriction Resistance is the resistance between two surfaces because they only touch at a few points
  - When 2 surfaces touch, with sufficient force, a small area of intimate metal-to-metal contact is formed.
  - It is important to differentiate between two surfaces touching and an “Ohmic contact”.
  - An Ohmic contact is one where the current and voltage follow a linear relationship i.e Ohm’s law holds V=IR

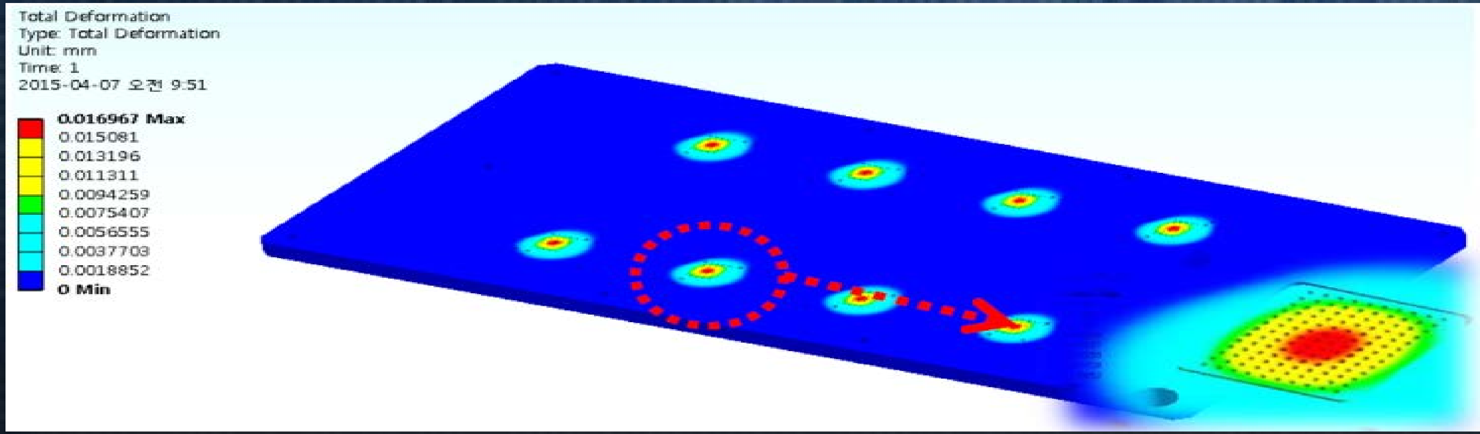
Current flow lines in body of contact



FEA

- **…. Constriction Resistance**
  - Can we measure constriction resistance? **– we can't!**
  - Do we have enough Overdrive? **– maximizing the overdrive didn't improve stability**
  - Is warpage causing this contact stability? **– let's check FEA data**

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, and other physical effects. **Finite element analysis** shows whether a product will break, wear out, or work the way it was designed



Warpage

- **FEA: Socket Warpage**
  - Our socket material are mostly Ceramic Peek and Ceramic
  - Comparing the warpage analysis from Ceramic as baseline, Peek material had huge warpage number.
  - With ceramic peek, the pins can't maintain good contact with PCB during probing action.
  - Is Ceramic the best way to go… any better plastic available?

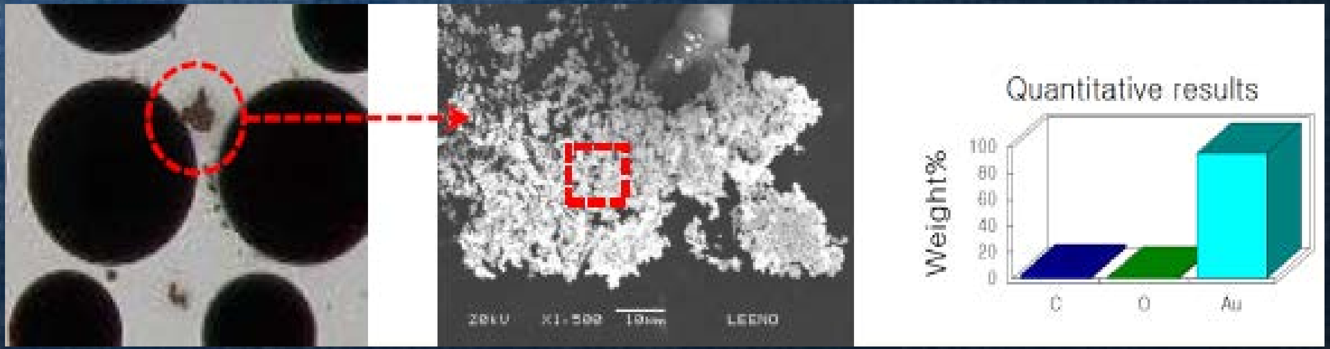
Socket Material	Warpage Data (in microns)			
	1.25" round	2.25" round	3.2" round	Rectangular SRASP
Ceramic Peek	29	48	116	27
Ceramic	1	1	3	1

Ceramic Peek – PEEK filled with ceramic

Debris on Ceramic

- **Ceramic**
  - One of standard socket materials for probe cards in TI
  - Debris on Ceramic sockets were noticed on every probecard.
  - Need to look for a socket material that is better than Peek and perform close to ceramic?

Debris are Au based on FA



New Socket Material

- **The MDS100**
  - High strength, low moisture absorption, high stiffness ~ dimensional stability
  - Better resistance to bending than Peek material

Socket Material	Warpage Data (in microns)			
	1.25" round	2.25" round	3.2" round	Rectangular SRASP
Ceramic Peek	29	48	116	27
Ceramic	1	1	3	1
MDS100	10	16	48	12

Mechanical Properties	Ceramic PEEK	MDS100
Tensile strength	13,000psi	14700 psi
Tensile elongation	>10%	1.50%
Tensile modulus	650,000psi	1,500,000psi
Flexural strength	23,000 psi	20,500psi
Flexural modulus	650,000psi	1,420,000 psi
Coefficient of Linear Thermal Expansion	2.0 x10-5	1.1 x10-5
Water absorption	0.37%	0.1%

Debris Minimized

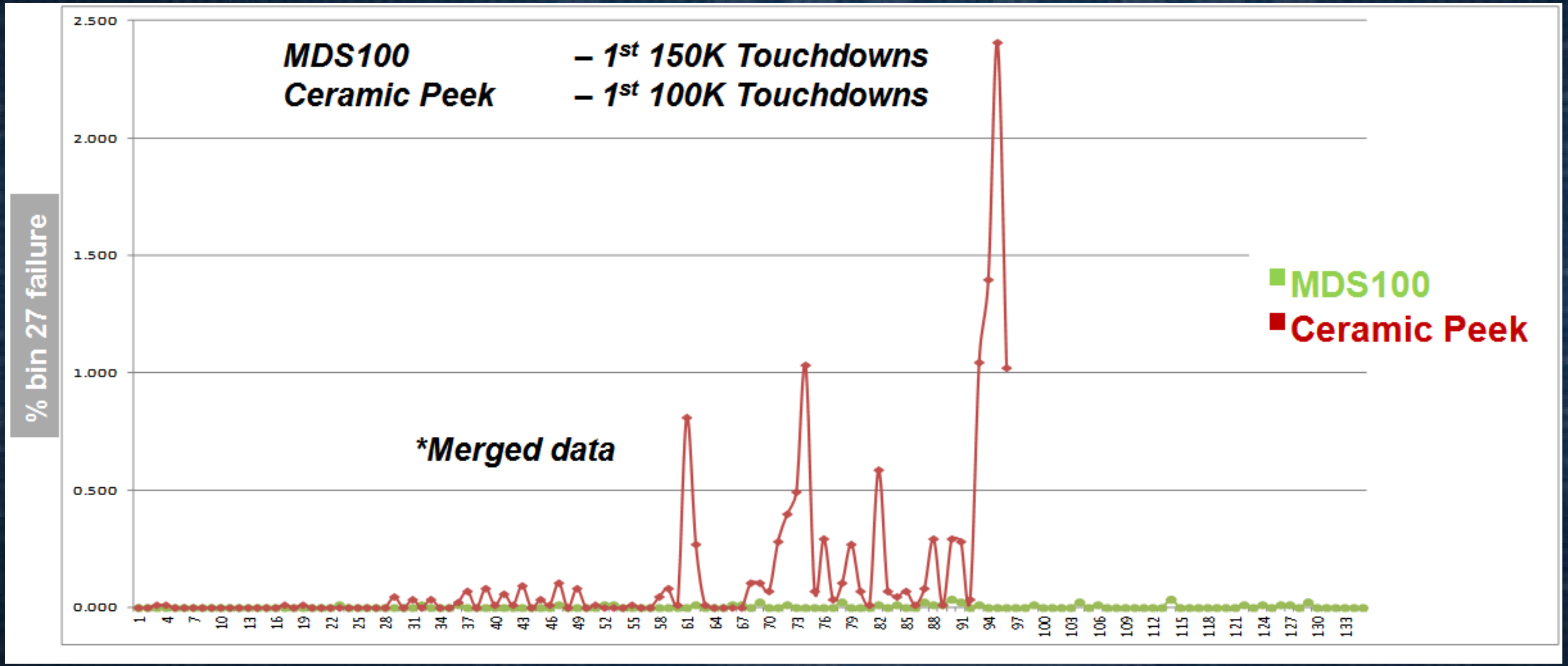
- **The MDS100 vs Ceramic socket material**
  - Ceramic material can cause more debris over time

2M touchdown

200k touchdown

Results

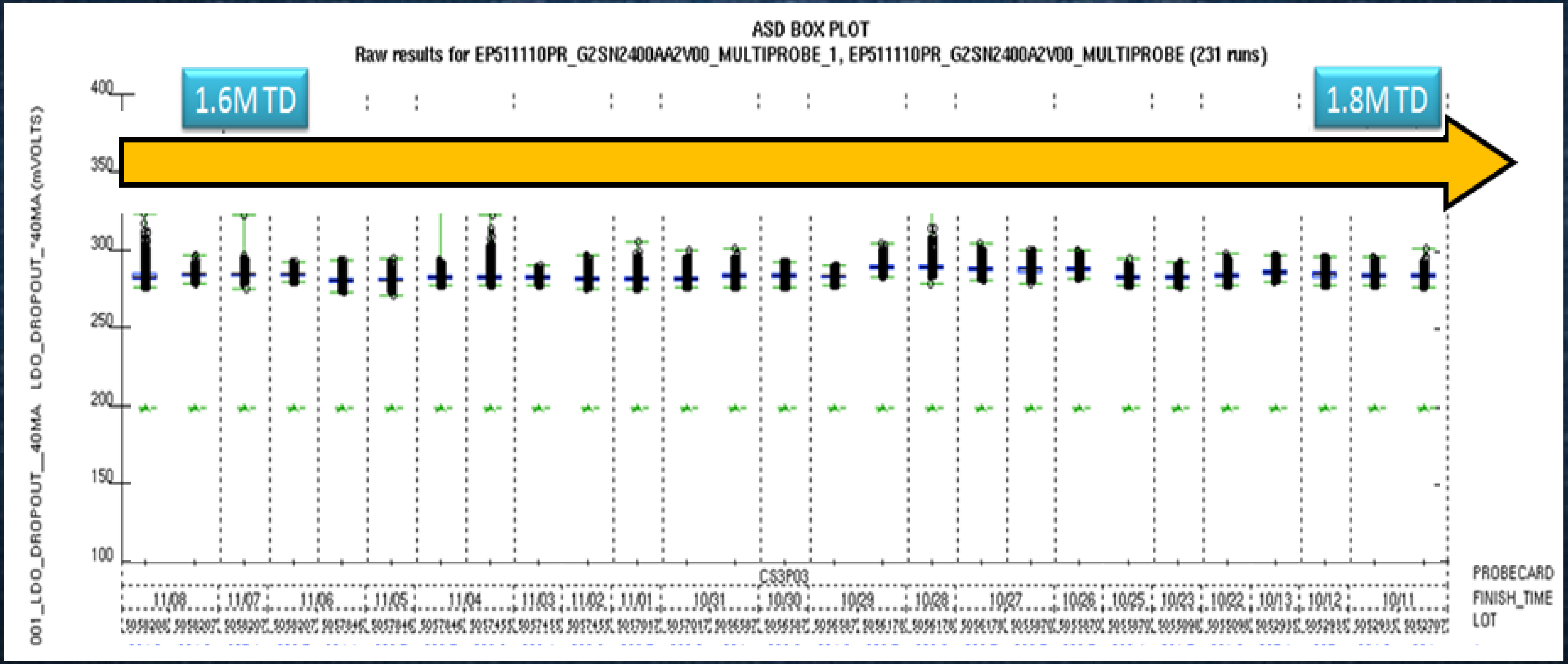
- **MDS100 Socket Material**
  - Pogo pins from Peek at 100k TD were all transferred and installed to the MDS100 socket



Peek material show degradation after probing multiple wafers
MDS100 on the other hand maintained the performance

Results

- **MDS100 – Stability to the new level**
  - Stable at 1.8M touchdown (glitches due to bad tester events)



Results

- **High Volume Manufacturing Validation**
  - Ceramic Peek vs MDS100 (MTdBF – Mean Touchdown between Failure)

			OLD PROBEHEAD MATERIAL			NEW PROBEHEAD MATERIAL		
DEVICE NAME	PROBE CARD ID	Card trackowkrs status	touch down made	no of failure	MTdBF	touch down made	no of failure	MTdBF
BQ8035	JB8P01	Active	1,028,555	41	24,489	566,017	0	566,017
	JB8P02	Active	717,043	40	17,489	497,225	0	497,225
	JB8P03	Active	708,268	31	22,133	414,231	0	414,231
	JB8P04	Active	797,913	48	16,284	413,175	0	413,175
	JB8P05	Active	429,846	62	6,823	490,838	0	490,838
	JB8P06	Active	529,872	44	11,775	560,113	0	560,113
	JB8P07	Active	724,872	54	13,179	451,169	0	451,169
	JB8P08	Active	793,194	17	44,066	474,774	0	474,774
	JB8P09	Active	[illegible]	39	16,850	[illegible]	[illegible]	445,841
	JB8P10	Active	[illegible]	36	2,752	[illegible]	[illegible]	406,340
SN2400	CS3P03	Active	543,949	11	45,329	1,624,660	0	1,624,660
	CS3P04	Active	949,363	26	35,162	1,310,117	0	1,310,117
	CS3P06	Active	1,340,831	12	103,141	235,546	0	235,546
	CS3P08	Active	251,913	8	27,990	321,918	0	321,918
	CS3P09	Active	474,574	10	43,143	1,458,150	1	729,075
	CS3P10	Active	458,747	14	30,583	874,156	0	874,156
	CS3P11	Active	434,491	9	43,449	504,520	0	504,520
	CS3P12	Active	1,670,889	17	92,827	582,024	0	582,024
	CS3P13	Active	398,479	6	56,926	670,876	0	670,876
	CS3P17	Active	1,308,330	10	118,939	373,251	0	373,251
	CS3P18	Active	590,177	10	53,652	1,009,908	0	1,009,908
TPS61254	PT6P01	Active	2,000,507	13	142,893	146,020	0	146,020
	PT6P04	Active	1,747,757	7	218,470	74,576	0	74,576
TPS65195	CS7P01	Active	1,088,594	11	90,716	117,490	0	117,490
	CS7P06	Active	1,334,362	10	121,306	890,361	0	890,361
TPS61162	DQ6P02	Active	4,857,621	15	303,601	895,109	0	895,109
	DQ6P03	Active	699,752	39	17,494	189,487	0	189,487
TPS65132	DR6P13	Active	3,550,061	19	177,503	648,813	0	648,813
	DR6P06	Active	226,757	16	13,339	370,695	0	370,695

65,942

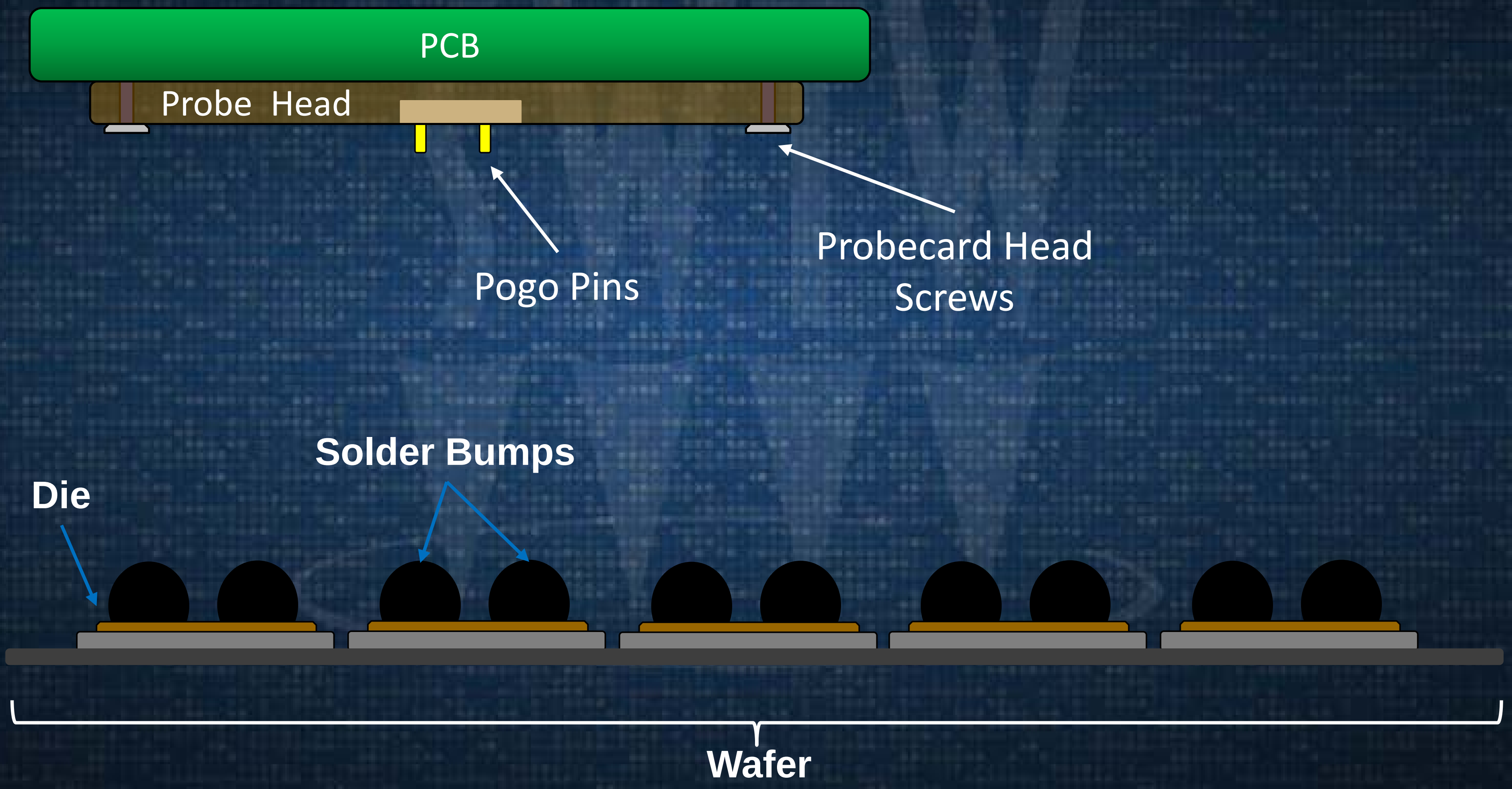
561,666

Results

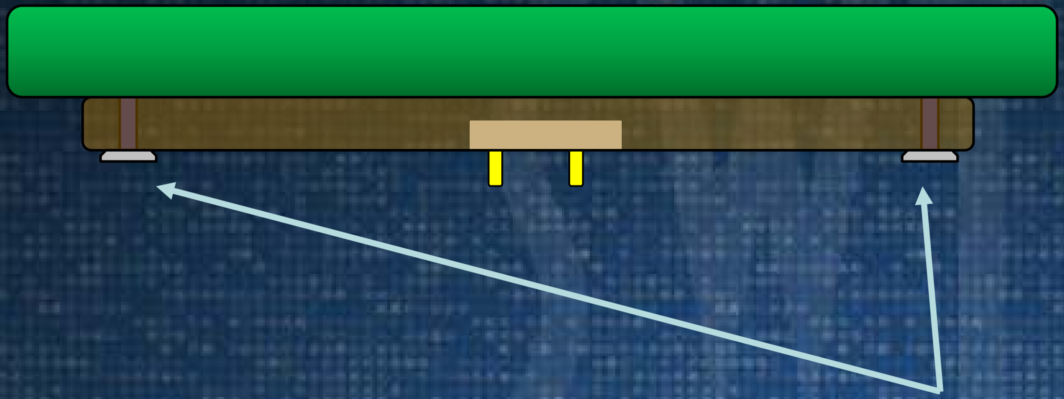
- **Stability on MDS100 socket**
  - Improved stability to 500k to 1 million touchdown between failures
  - Downtime assist decreased, our manpower can attend to other issue effectively
  - Tester utilization increased, output and cycle time entitlement can be achieved

- **Cost**
  - Avoid spending on additional set of hardware to cover the capacity loss
  - Decreased spare pogo pin usage due to early replacement
  - Pin life can reach 6M touchdown or wear out up to 10um tip to valley of the crown pin

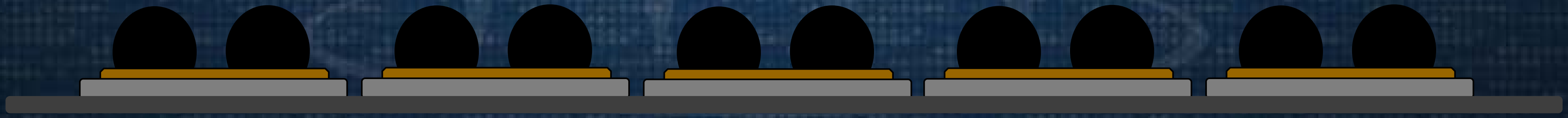
Quality – Damage Bump



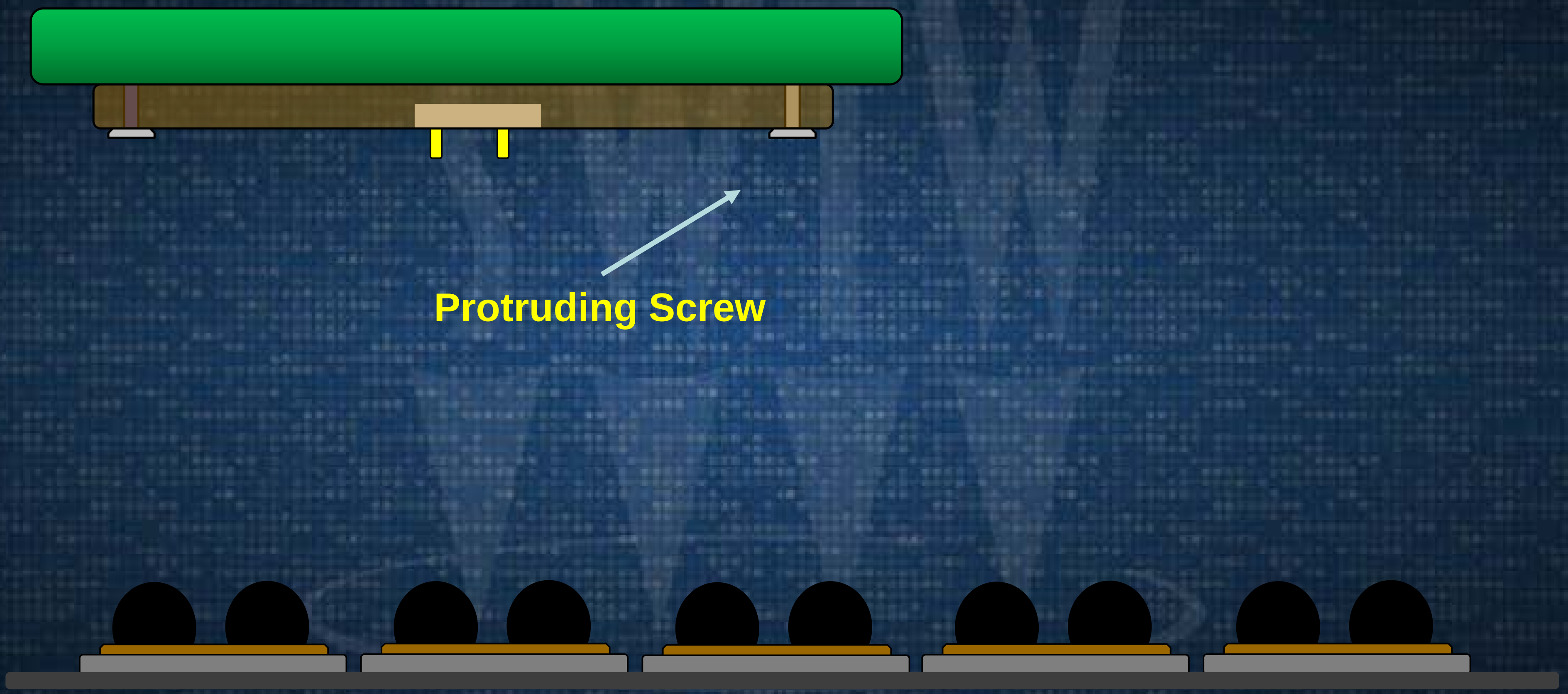
Quality – Damage Bump



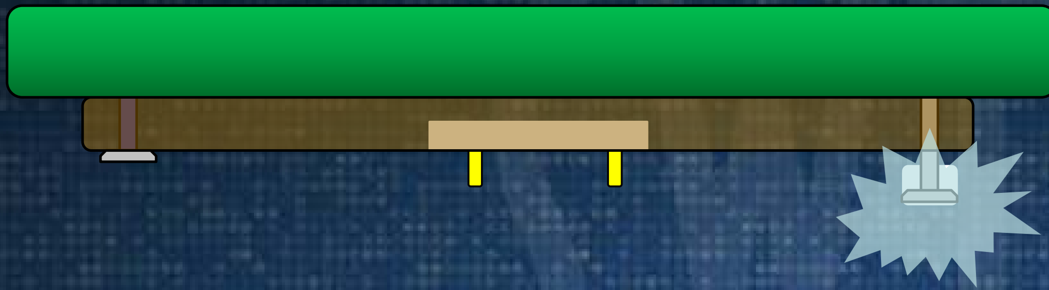
1) Got loose over time
2) Not tightened properly during maintenance due to high fail rate and assists

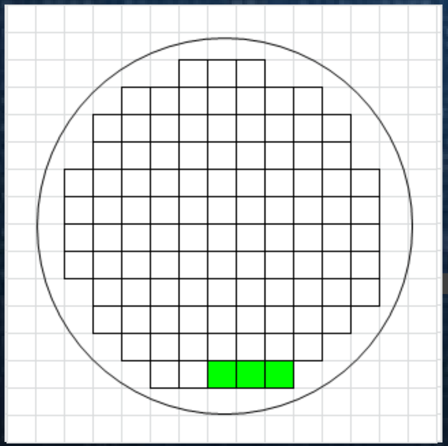


Quality – Damage Bump



Quality – Damage Bump

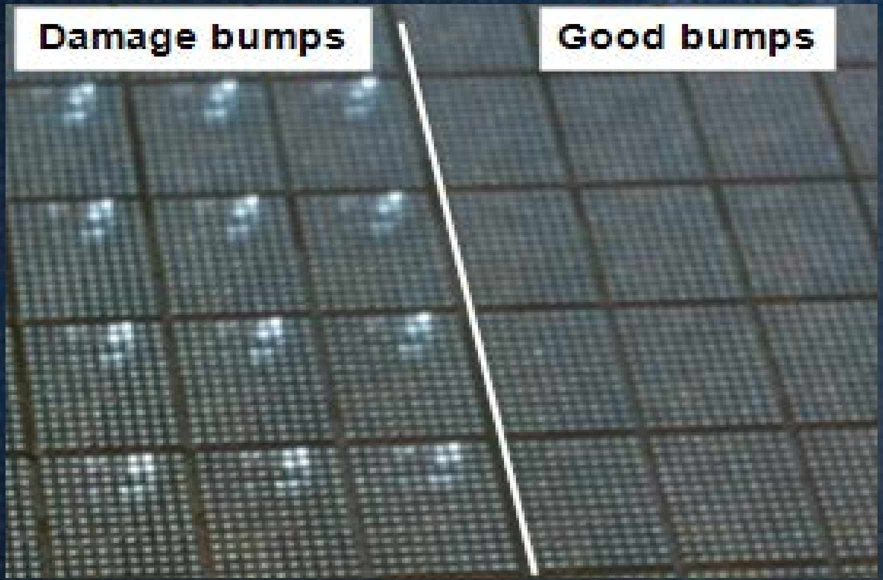


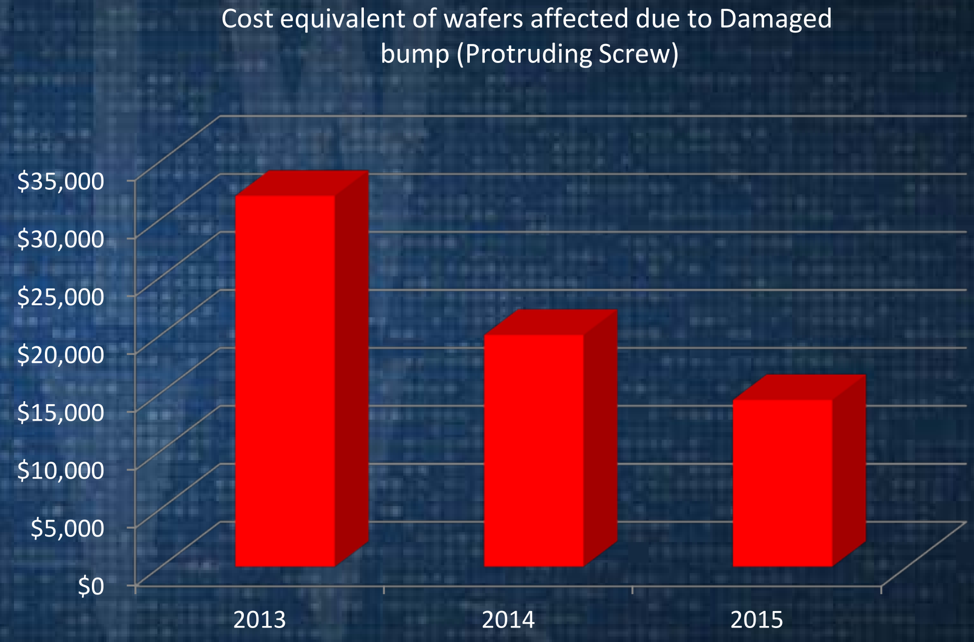


- Damaged bump will be induced on the units that already passed electrical testing.

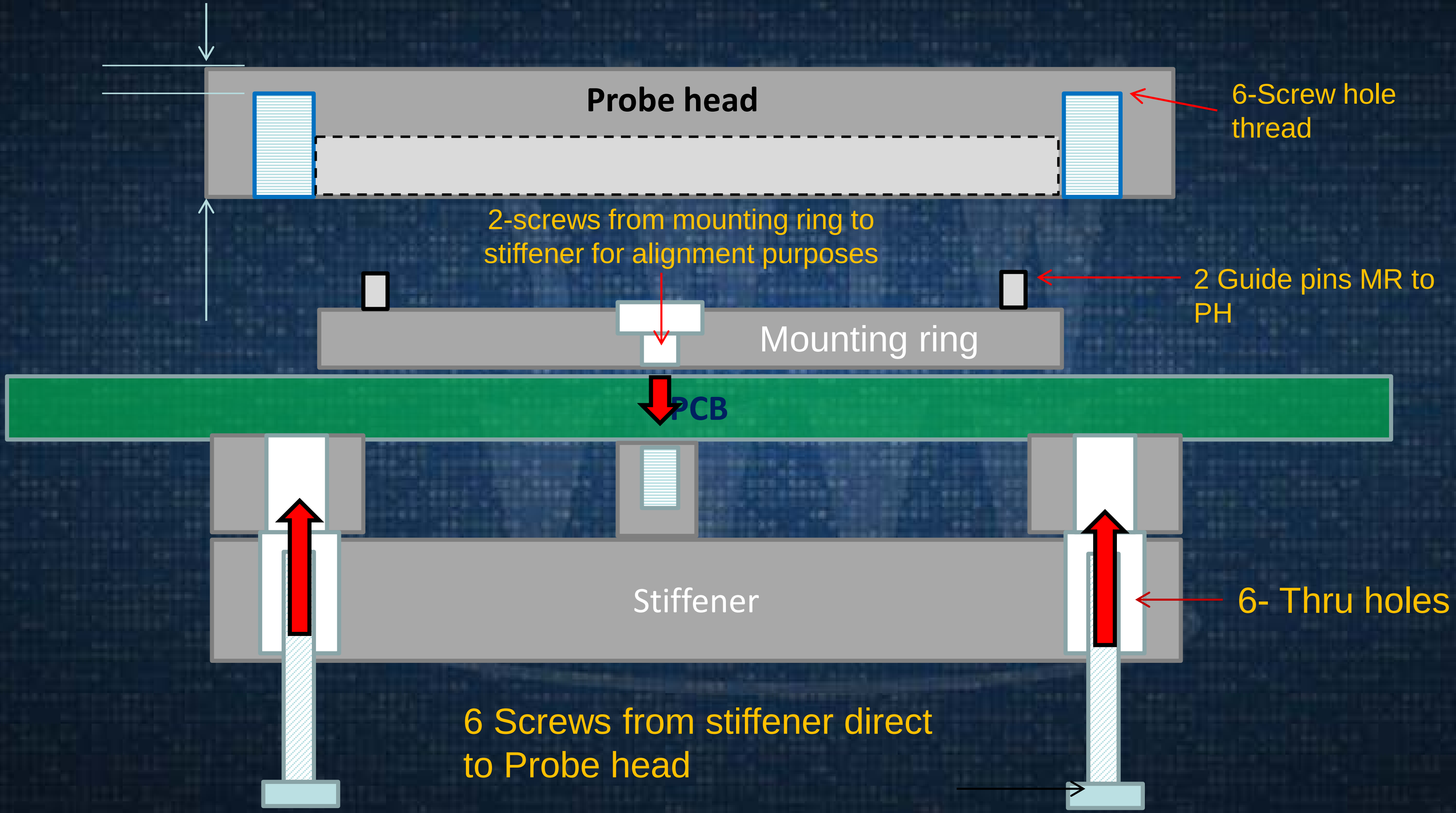
Quality – Damage Bump

- **Damage Bump due to protruding screw**



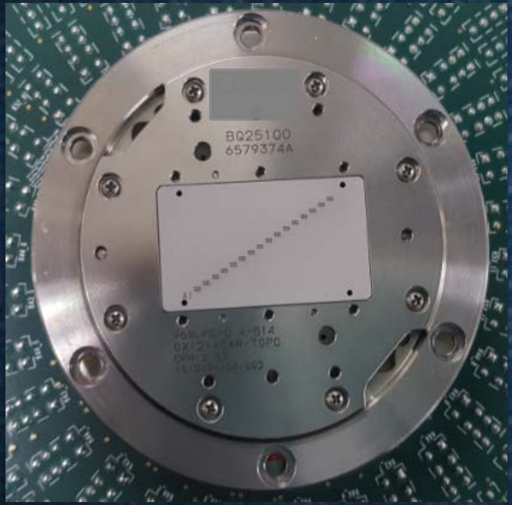


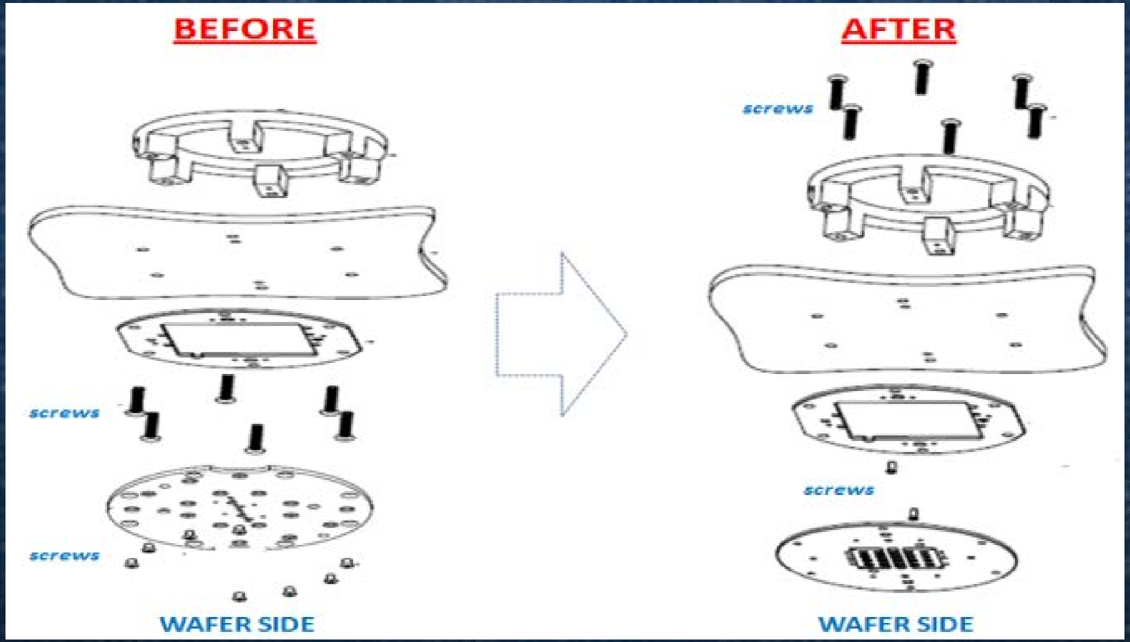
Reverse Screw Design Concept

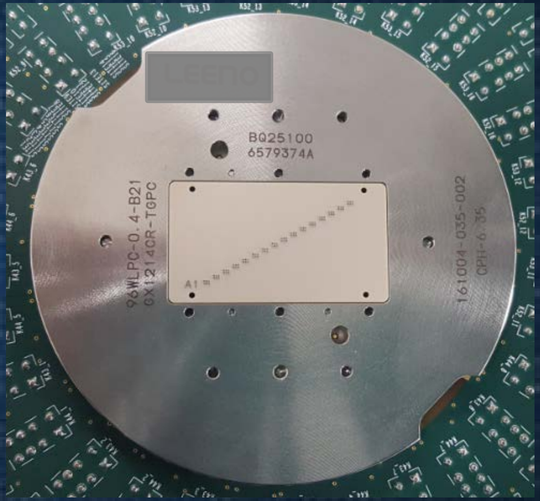


Approach

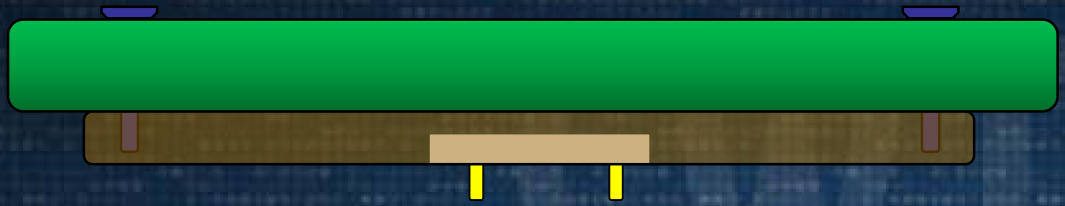
- **The Reverse Screw Design – moving away from the norm to eliminate quality risk**
  - Maintained the same standards on the PCB – use the same PCB. No additional cost!
  - Just replace the probe head

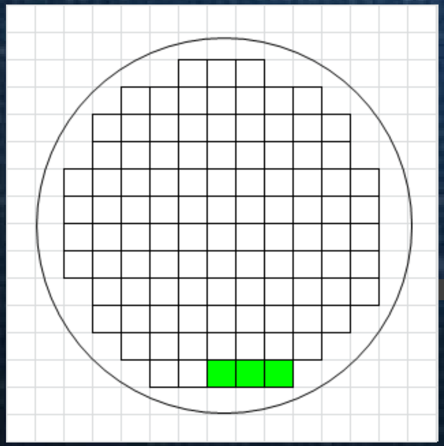






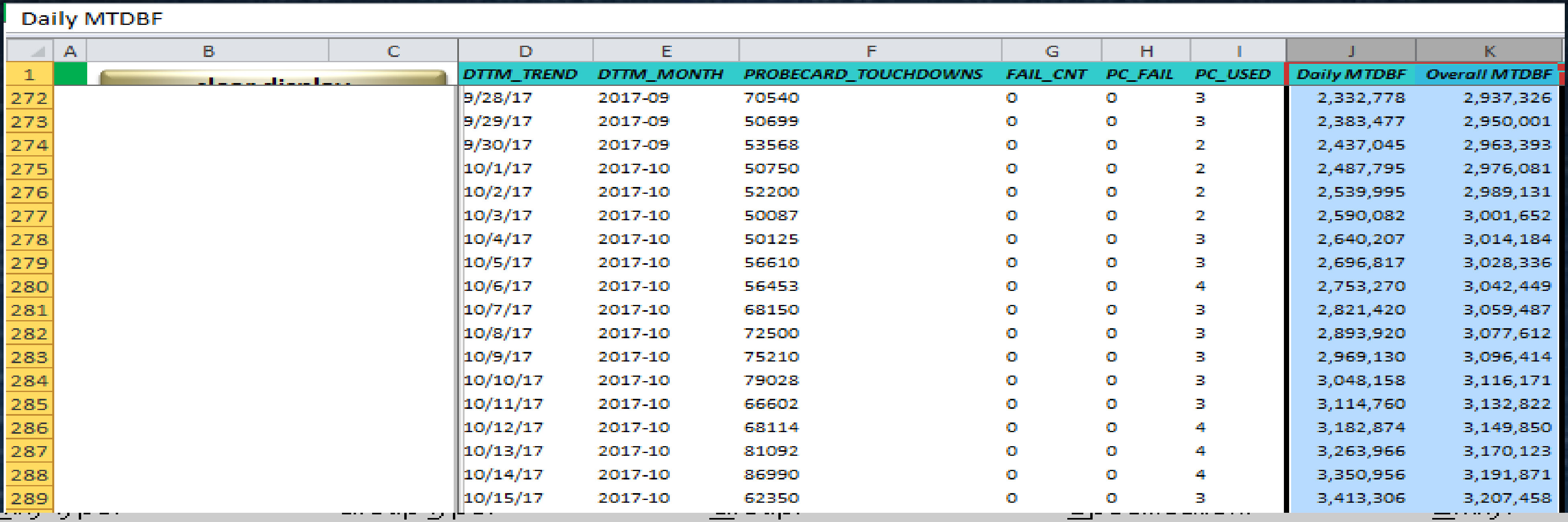
Results





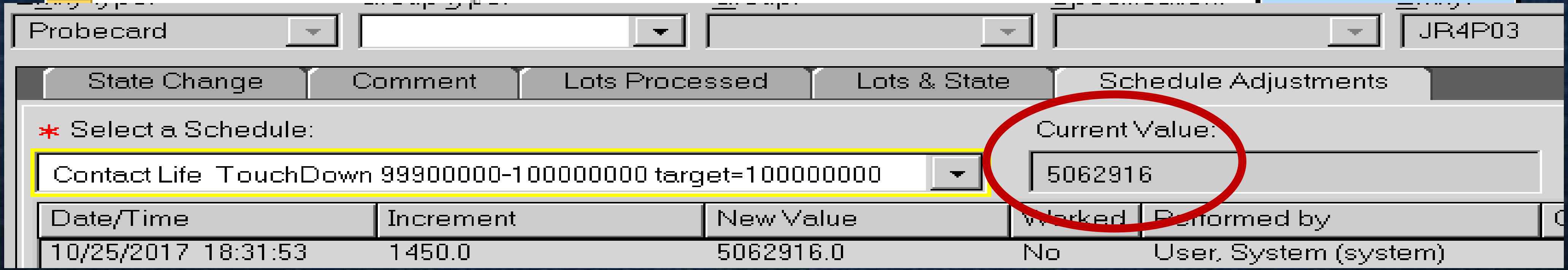
- Zero out the risk of inducing damaged bump during probing.
- Zero damage bump event on new built cards since 2016

TMP103 JR4Pxx MTdBF



Daily MTDBF

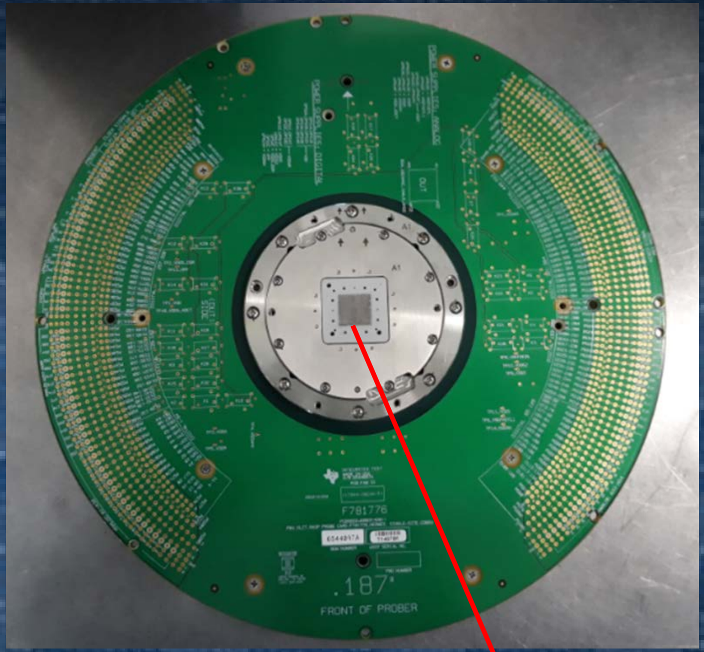
	DTTM_TREND	DTTM_MONTH	PROBECARD_TOUCHDOWNS	FAIL_CNT	PC_FAIL	PC_USED	Daily MTDBF	Overall MTDBF
272	9/28/17	2017-09	70540	0	0	3	2,332,778	2,937,326
273	9/29/17	2017-09	50699	0	0	3	2,383,477	2,950,001
274	9/30/17	2017-09	53568	0	0	2	2,437,045	2,963,393
275	10/1/17	2017-10	50750	0	0	2	2,487,795	2,976,081
276	10/2/17	2017-10	52200	0	0	2	2,539,995	2,989,131
277	10/3/17	2017-10	50087	0	0	2	2,590,082	3,001,652
278	10/4/17	2017-10	50125	0	0	3	2,640,207	3,014,184
279	10/5/17	2017-10	56610	0	0	3	2,696,817	3,028,336
280	10/6/17	2017-10	56453	0	0	4	2,753,270	3,042,449
281	10/7/17	2017-10	68150	0	0	3	2,821,420	3,059,487
282	10/8/17	2017-10	72500	0	0	3	2,893,920	3,077,612
283	10/9/17	2017-10	75210	0	0	3	2,969,130	3,096,414
284	10/10/17	2017-10	79028	0	0	3	3,048,158	3,116,171
285	10/11/17	2017-10	66602	0	0	3	3,114,760	3,132,822
286	10/12/17	2017-10	68114	0	0	4	3,182,874	3,149,850
287	10/13/17	2017-10	81092	0	0	4	3,263,966	3,170,123
288	10/14/17	2017-10	86990	0	0	4	3,350,956	3,191,871
289	10/15/17	2017-10	62350	0	0	3	3,413,306	3,207,458

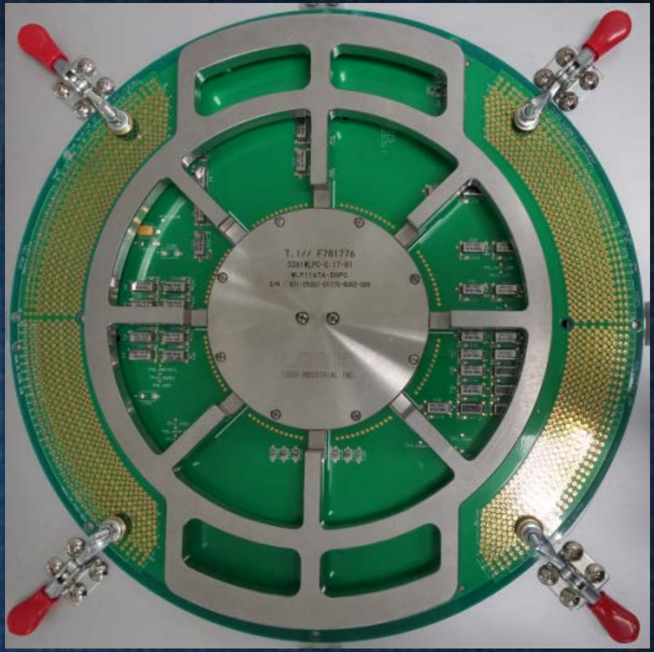


New Applications

- **Flip Chip (from Cobra to Pogo)**

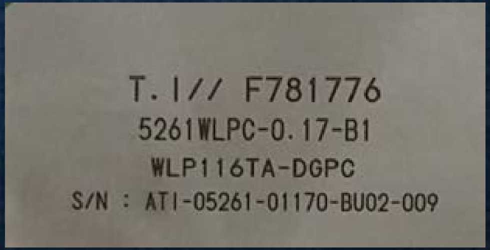
TI Probe Card Technology Name	WSP-FC (FLAT)
PC Vendor Pin Part Number	WLP116TA-DGPC
Probe Depth	6.40mm
Min Pitch	125um
Contact Force	5gm
Tip Diameter	90um
Other Information	Non-Kelvin
Device Info	
Testing Temperature	30^{o}C
Min Pitch	190um
Feature Type	Bump
Min Feature Dimensions	~100um dia.
# Pins / Site	5261
# Sites	1
Total Probe Count	5261
Die / Wafer	250
Tester	VLCT RASP X1
Prober	TSK





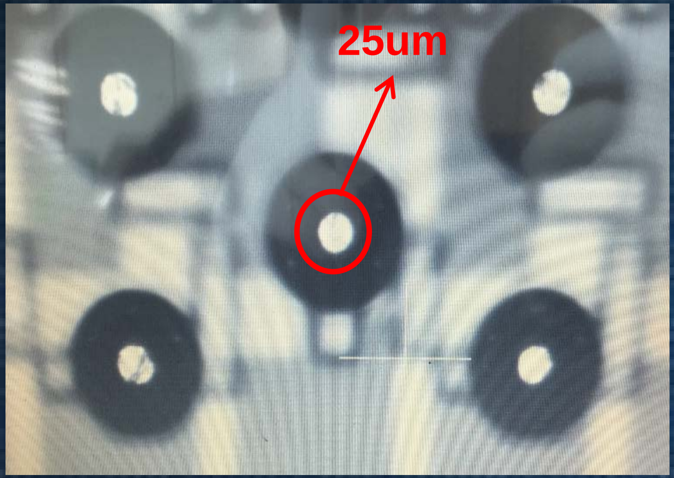
Technology	Status
Cantilever	Qualified
Vertical	Qualified
Pogo Pin	In Process

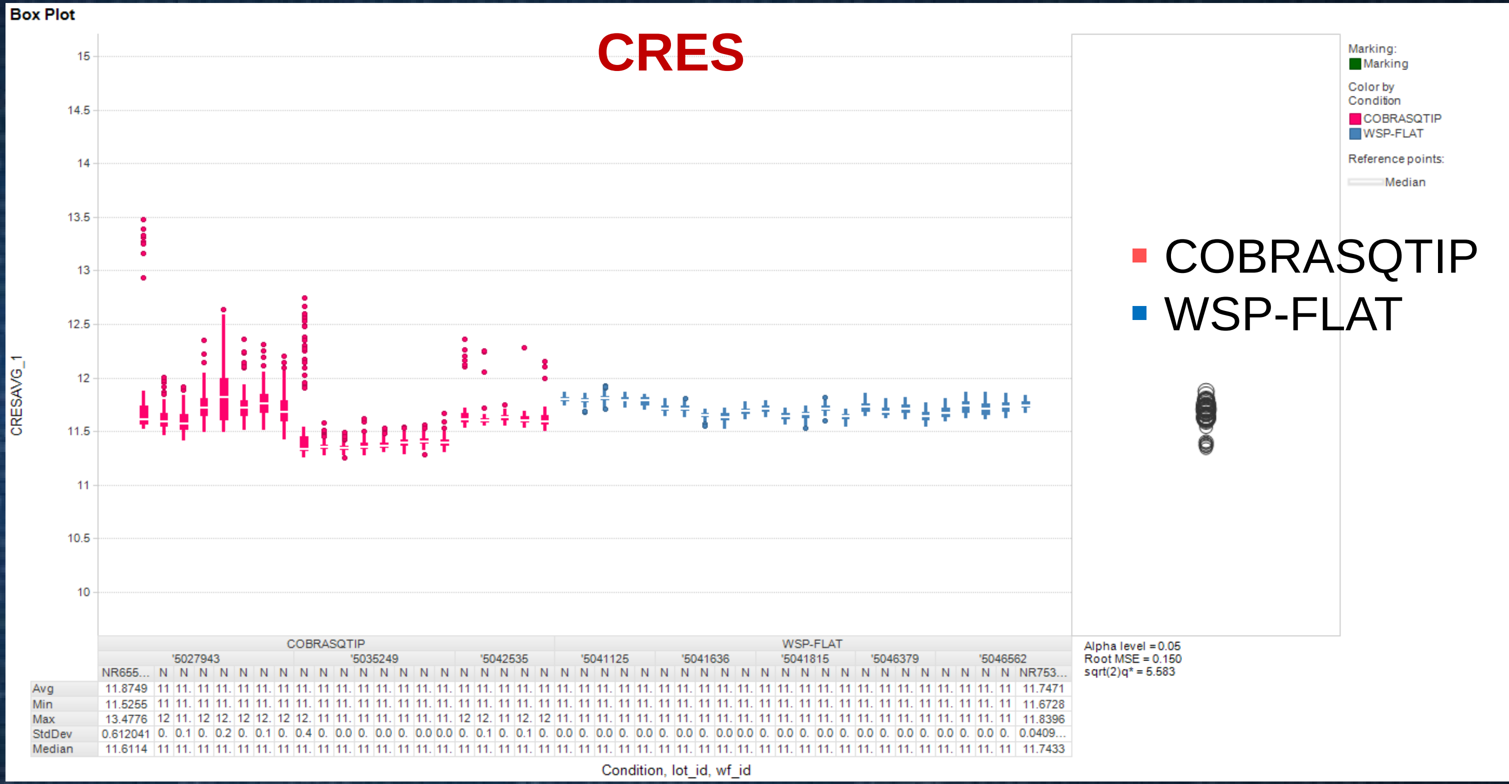
Device
Socket PN
Pin PN
Vendor SN



Pogo on Flip chip

- **CRES and Bump Damage**

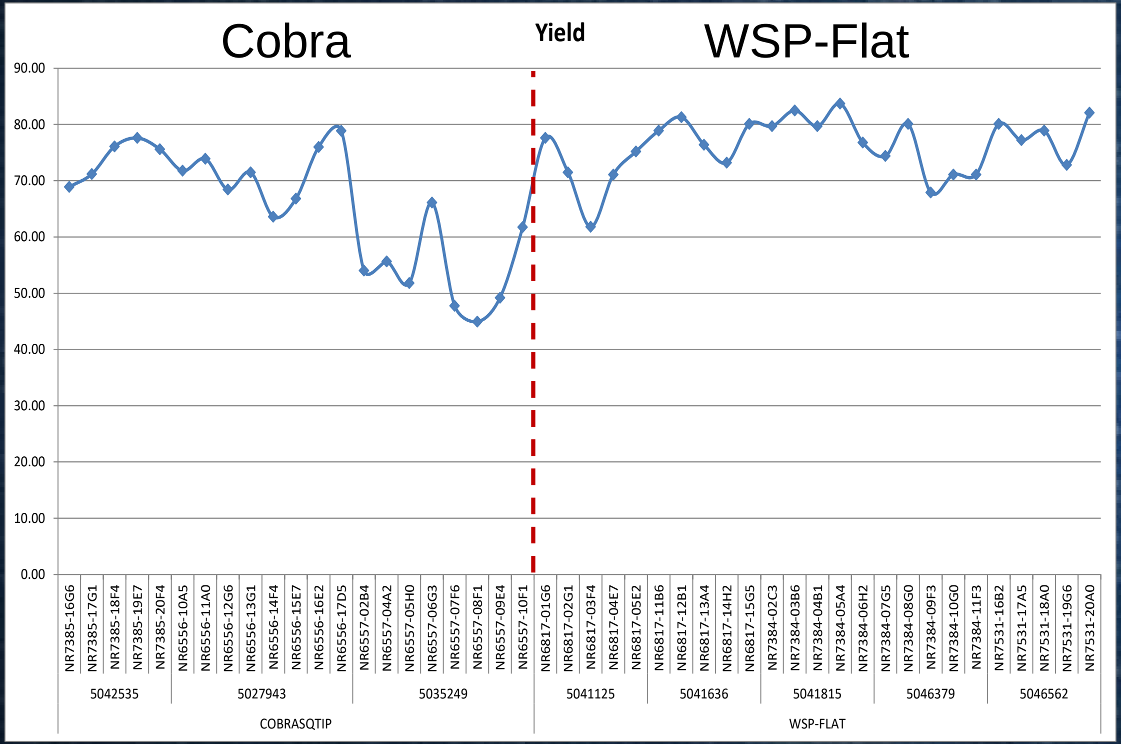


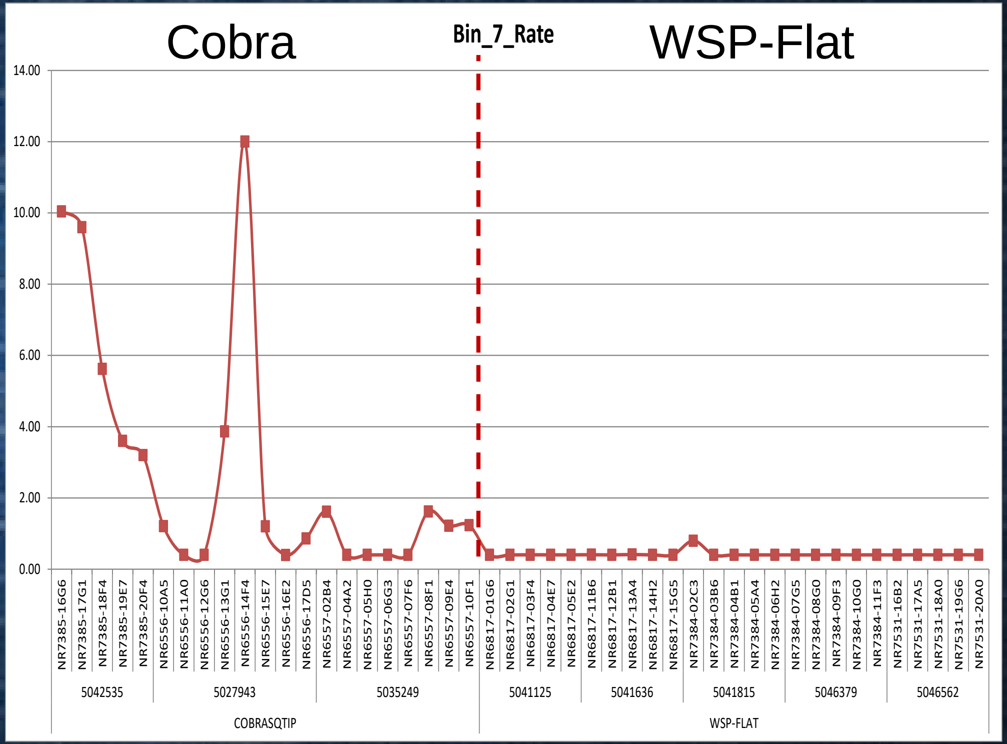


**CRES reading and stddev is lower on WSP-FLAT (both are new pins and socket)

Pogo vs Cobra

- **Yield and Contact Open (Bin7)**





MTdBF = 5k touchdown

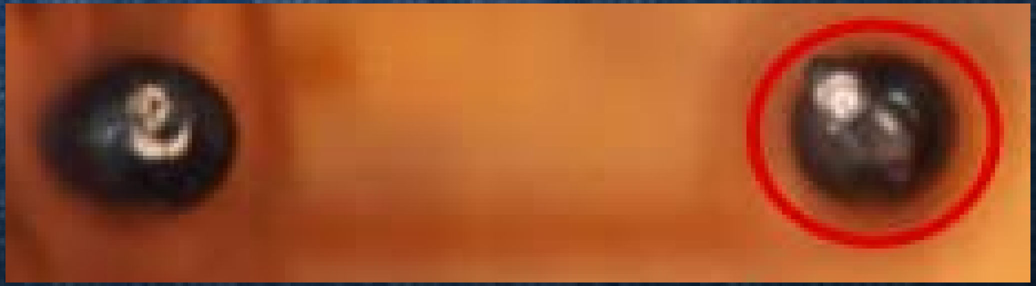
MTdBF > 100k+ touchdown

New Applications

- **Cu Pillar**
  - In Cu Pillar space, we have Cantilever and Vertical technology.
  - Pogo on-going high-volume production

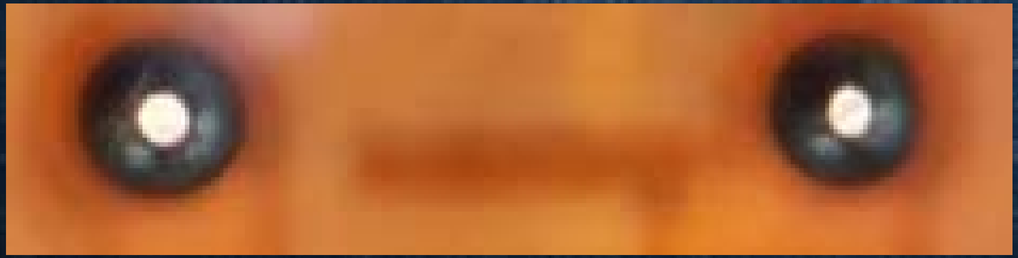
Technology	Status
Cantilever	Qualified
Vertical	Qualified
Pogo Pin	In Process

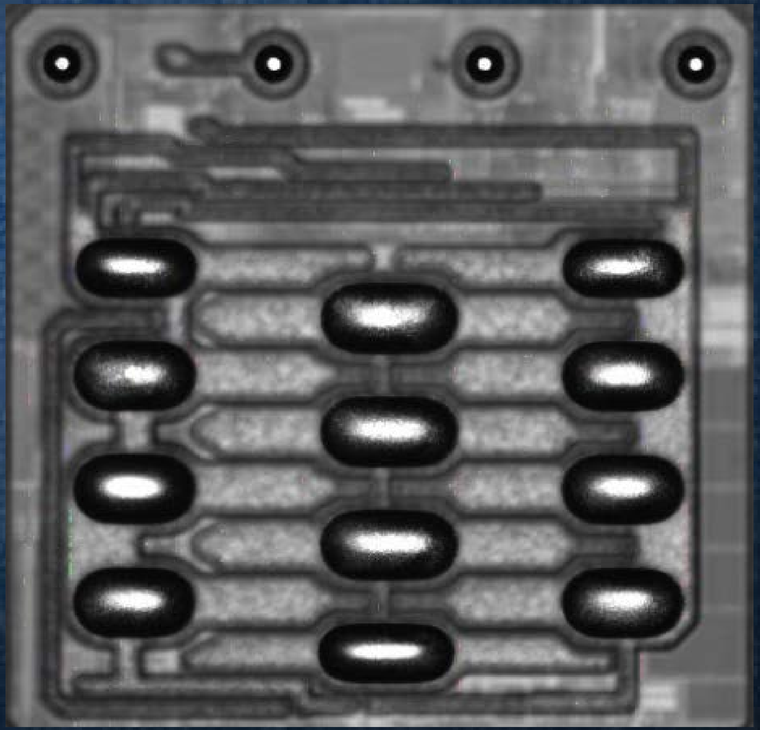
Issues on Vertical and Cantilever technology:



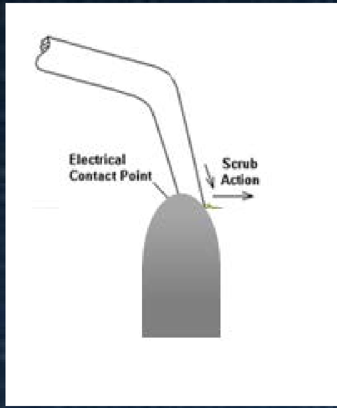
New Applications

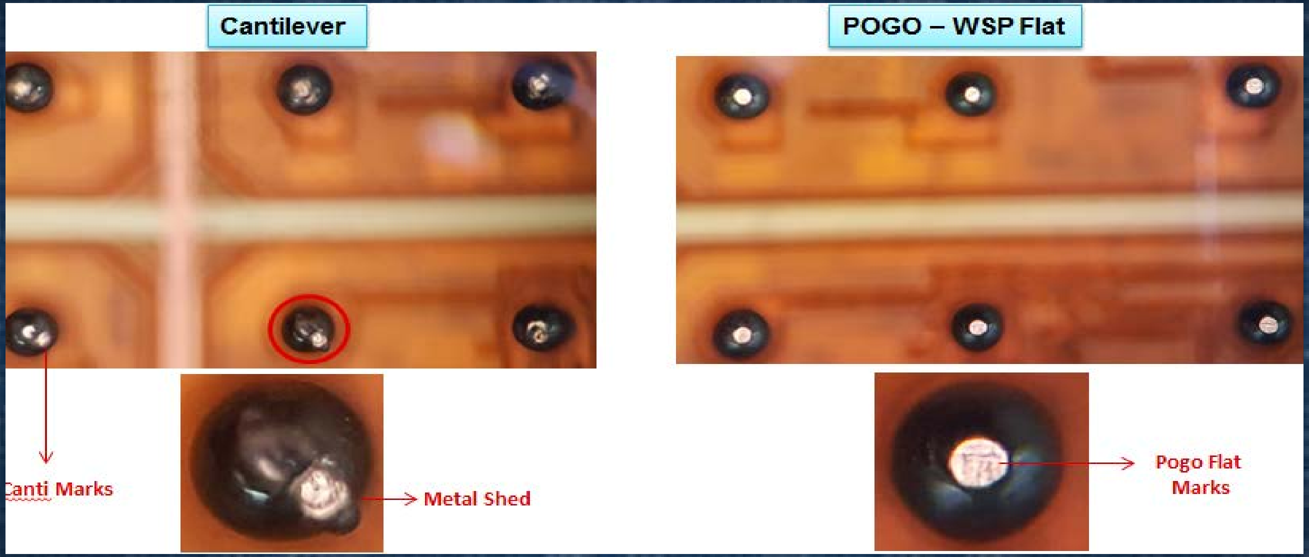
- **Cu Pillar: Pogo Pin Cu Post damage**
  - Advantage of pogo pin over cantilever and vertical

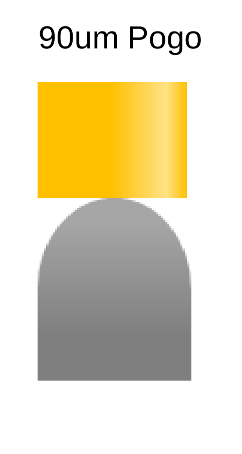


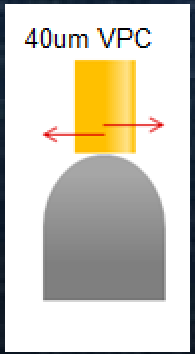


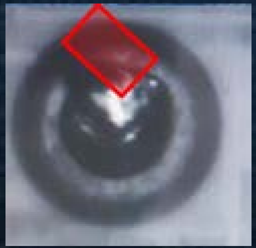
Cantilever, VPC and Pogo Probe Mark Comparison







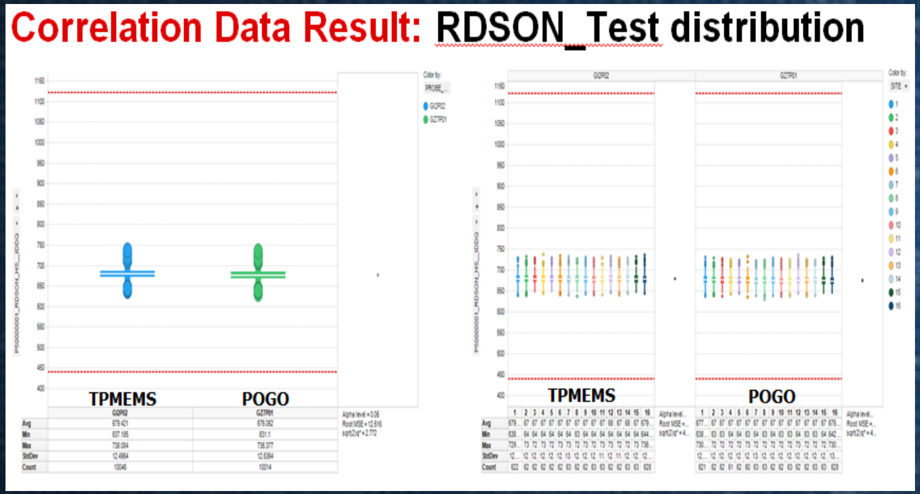


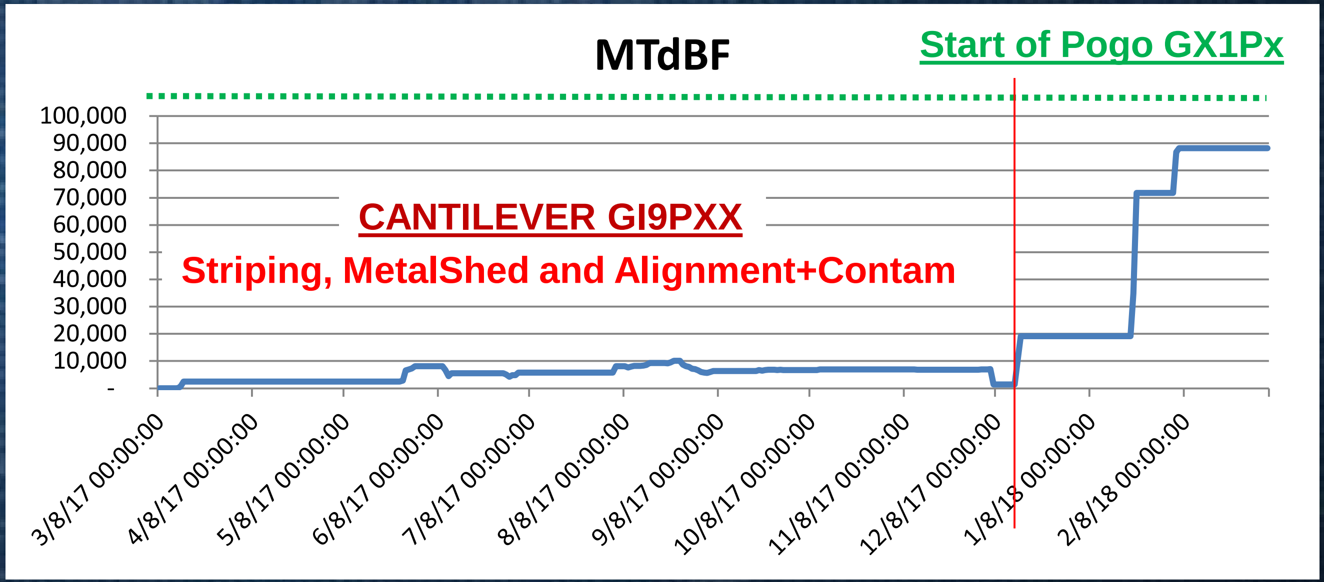


- **Cantilever can cause metal shed due to its scrub action**
- **Pogo probe marks on Hotrod post is centered, No risk of metal shed**
- **Electrical contact is stable, Yield is stable**

New Applications

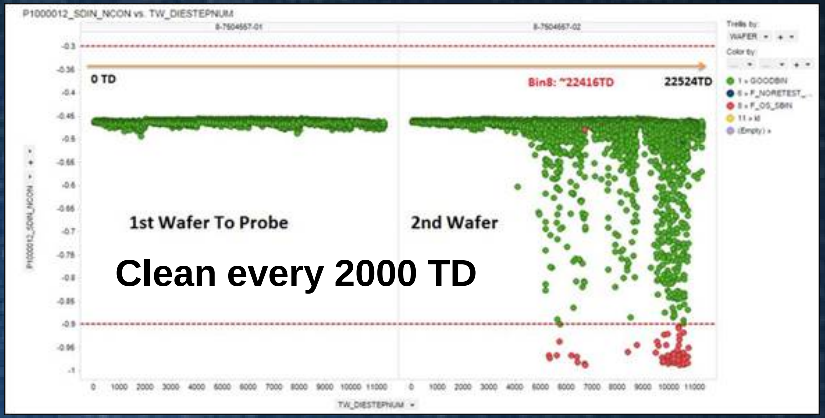
- **Cu Pillar: Pogo Pin**
  - Vertical electrical performance comparable with Pogo
  - Cantilever and Vertical have risk of metal shed/damage



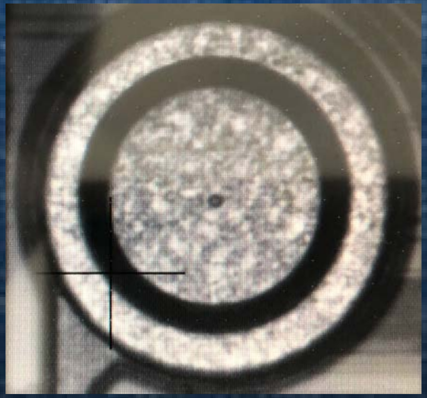


New Applications

- **CU RDL/UBM (150um)**

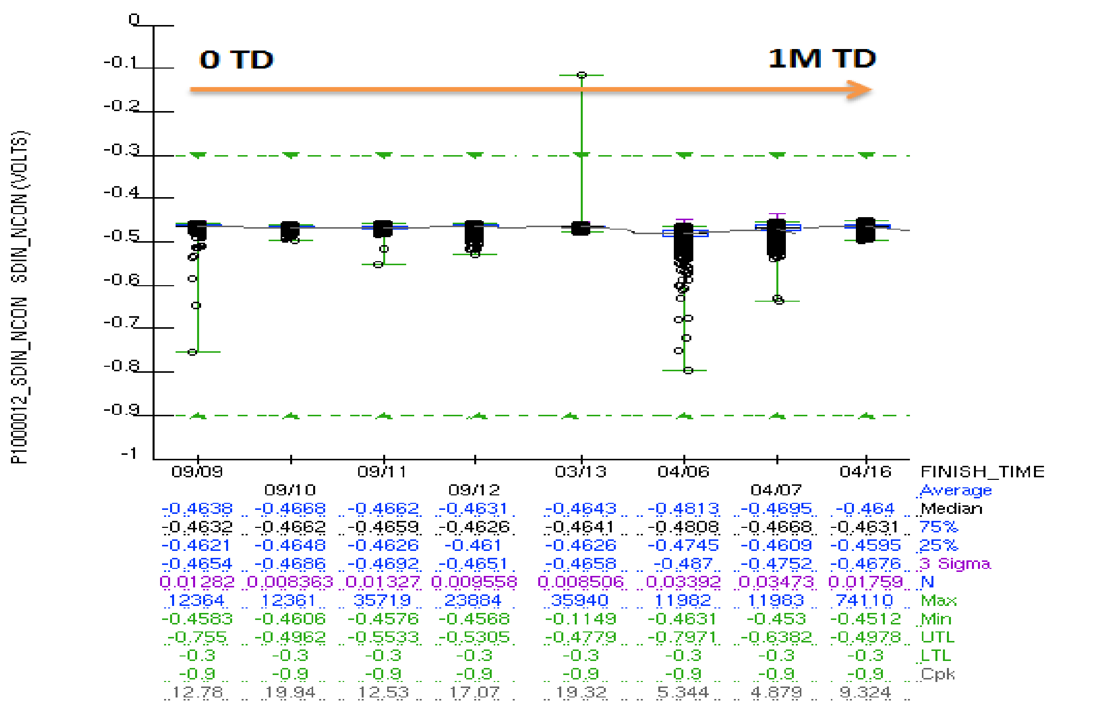


- Crown to Pointed Tip pogo
- Cleaning frequency started with 2000 touchdowns ~ unstable
- Works fine at 200 touchdown cleaning frequency.
- Need further study and optimization on cleaning



New Applications

- **CU Pad/UBM (150um)**



- +1M touchdown without failure
- Cost cheaper than VPC ~ 50%
- Same socket and can switch between UBM and Bump probing. Additional cost avoidance

Technology	Status
Cantilever	Qualified
Vertical	Qualified
Pogo Pin	In Process

Summary

- Pogo is low cost, easy to maintain, but superior technology
- Pogo Probecard performance or CRES can be impacted by the socket material
- MDS100 socket material can maintain good CRES throughout the pogo pin's life time (crown wear-out at 6M touchdown)
- Reversing the screw eliminates quality risk without any impact on performance and cost
- Using pogo on the space dominated by VPC can further improve production setup stability and cost.

Follow-on Work

- **Pointed tip wear-out over time**
- **Optimized cleaning on pointed tip pogo**
- **Multisite application for fine pitch pogo flat**
- **Reducing the spring force to 3gm for high pin count ~25k pins**
- **Application of pogo or similat technology on 60x60um Al pad**

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THANK YOU!