SWTEST
2021 CONFERENCE
PROBE TODAY,
FOR TOMORROW

30TH ANNIVERSARY

# Production Parametric Probe

## An Essential Guide to Lowering Cost of Test While Probing Very Small Pads

CELADON™
ULTRA HIGH PERFORMANCE PROBE CARDS

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Aug. 30 – Sep. 1, 2021

# Overview

- Introduction
- Background
- Products
- Expected Results & Goals
- Actual Results
- Benefits of Actual Results
- Cost of Ownership Model
- Conclusion & Next Steps

# Introduction

## Why are we here?

Global Foundries, Malta was facing ever-increasing probe card prices and decreasing test pad sizes. They approached Celadon with the goal of reducing cost of test (COT) and total cost of ownership (TCO)

# Background

**Celadon has been the preferred supplier in modeling and characterization, WLR, and ESD for almost a decade, working with all Global Foundries sites worldwide.**

**Celadon products used:**

- VersaCore (VC20E)
- VersaTile (TV19)
  - Single- & Multi-site
- Rail System
- Tile on Card (TOC)
  - T40
  - T90

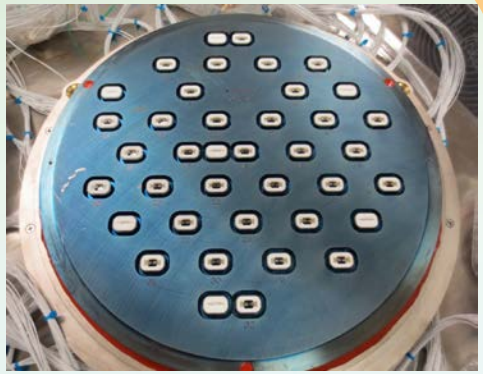
# Background

## Modeling and Characterization

Device Labs

Modeling Labs

Characterization Labs



## Wafer Level Reliability

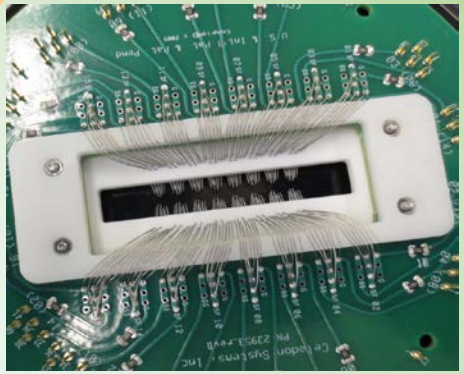
Reliability and Burn-In Labs

High Volume Manufacturing

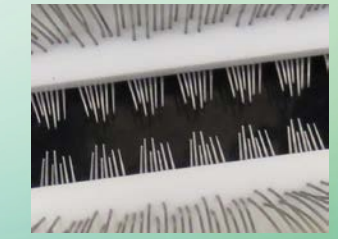
## Parametric Test

Device Labs

High Volume Manufacturing



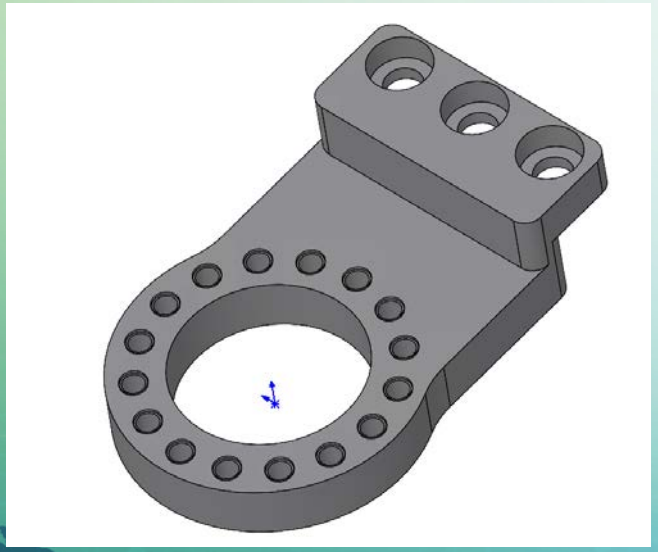
## Lower Pin count Multiprobe

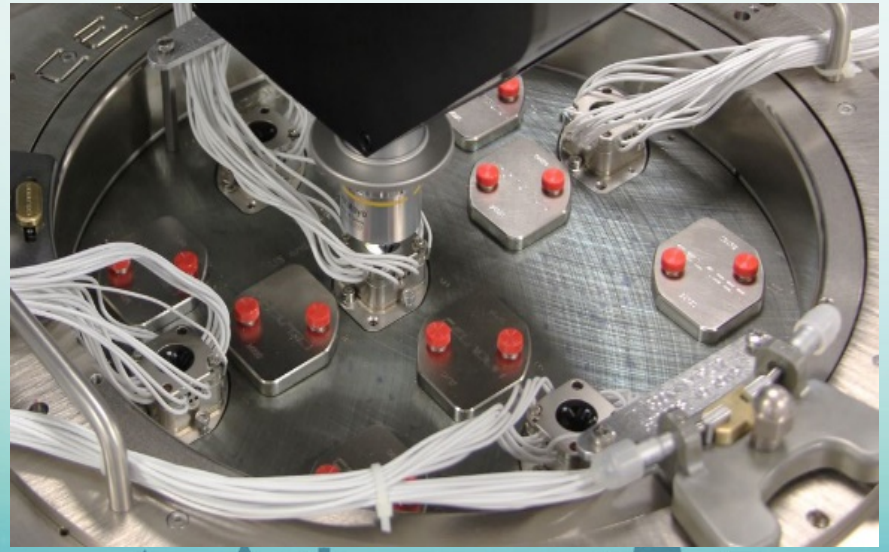


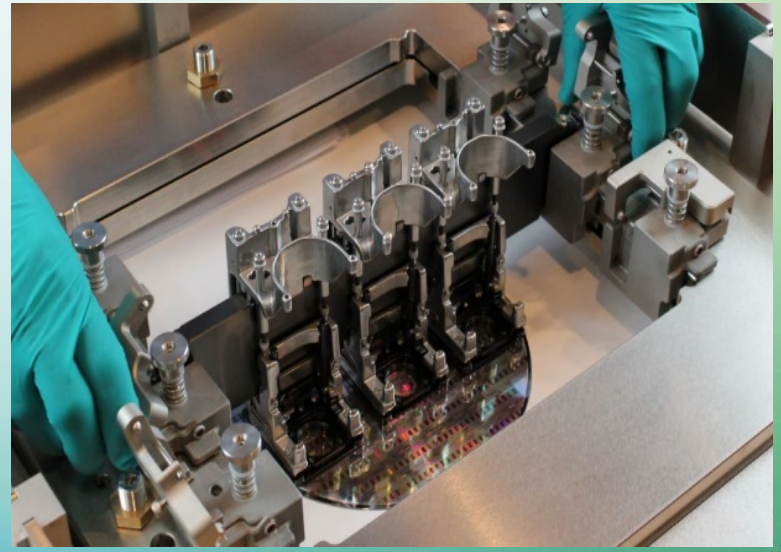
High Volume Manufacturing

# VersaTile™ TV19, VersaPlate™, and Rail System

- Standard Operating Temperature -65 to 300C
- Up to 32 probes per card
- Can mount to standard positioner arms, mounts to Celadon VersaPlate™
- Up to 17 VersaTiles™ on a 300mm VersAdjust™ system
- Up to 22 VersaTiles™ on a 300mm Rail system







# T40, T90, and TOC

### T40

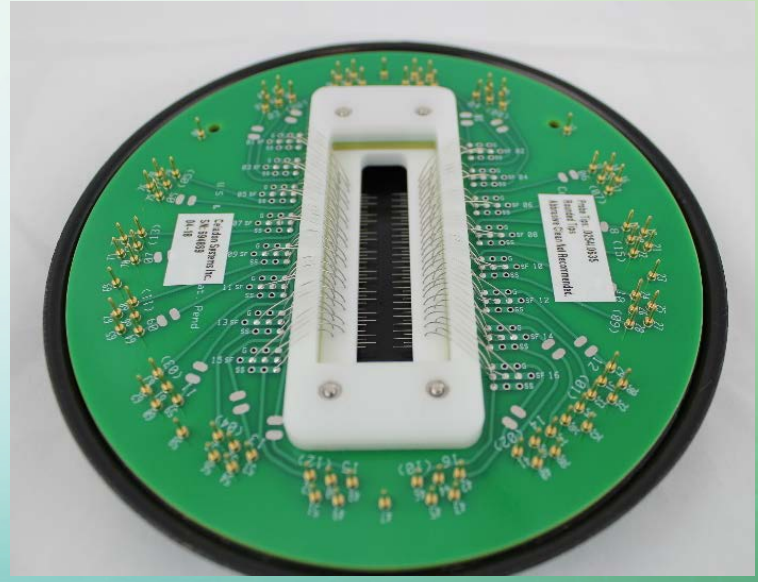
- Standard Operating Temperature -65 to 300C, optional to 600C
- Single site, up to 50+ pins


### T90

- Standard Operating Temperature -65 to 300C, optional to 600C
- Multi-site, up to 300+ pins

### TOC

- Standard Operating Temperature -65 to 300C, optional to 600C
- Varies by application

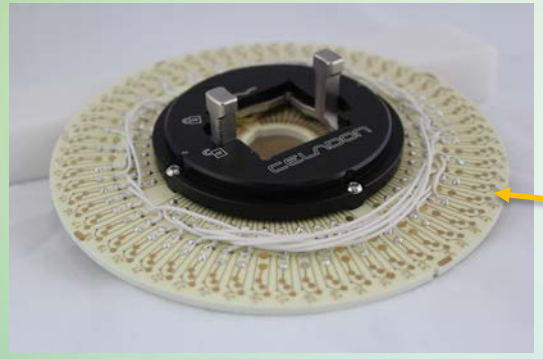


# VC20™ Production Parametric Probe card

**The VC20 is Celadon's most popular modular probe card. It is quick change and can be shifted easily from one style board to another - *less than a minute change time using our Insertion Tool.***

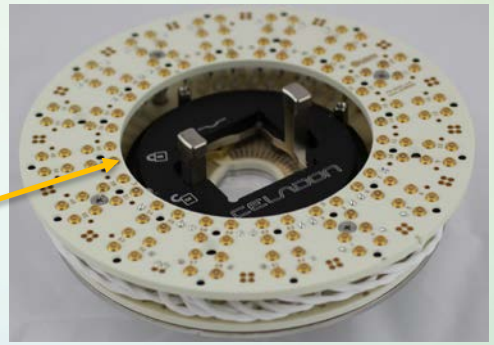
***VC20™ can handle up to 48 channels, is ultra low leakage (<5 fA/V at 100V), and is rated -65 to 200C***

***"Lab to Fab"***



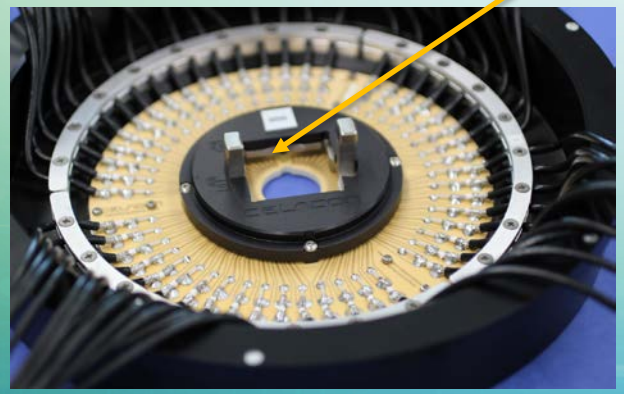
Keithley S600

VC20E™

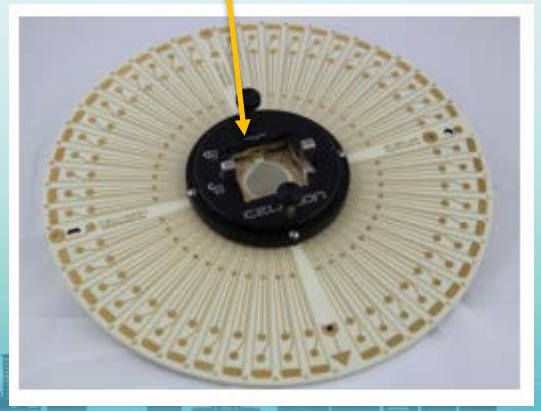


Keithley S530/S400

Custom cabled-out



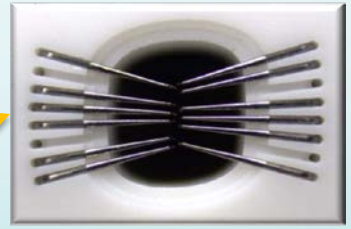
Keysight
4080
4072
4062



PCI-45E

# Celadon Systems – Quick Facts

- **Celadon has been in business 24 years. Celadon products are used by ~90% of semiconductor companies worldwide in addition to other applications including medical, space and defense.**
- **Celadon is a US based company: All of our engineering, manufacturing and repair is done in Burnsville, Minnesota.**
- **Celadon has 60 Patents and 15 Pending Patents**



- **Celadon's core competencies:**
  *Probe cards, Cables and Adaptor's*
- Technology: ***Advanced Cantilever***
  => In development: ***Vertical (Bamboo)***
- **Celadon's Core Values:**
  *Integrity, Innovation, Invention, Dedication*

# Qualification Expected Results

## Electrical Performance Goals

- Leakage: <1fA/V
- Contact Resistance: < 2Ω
- Gram Force: < 1g/mil

## Mechanical Performance Goals

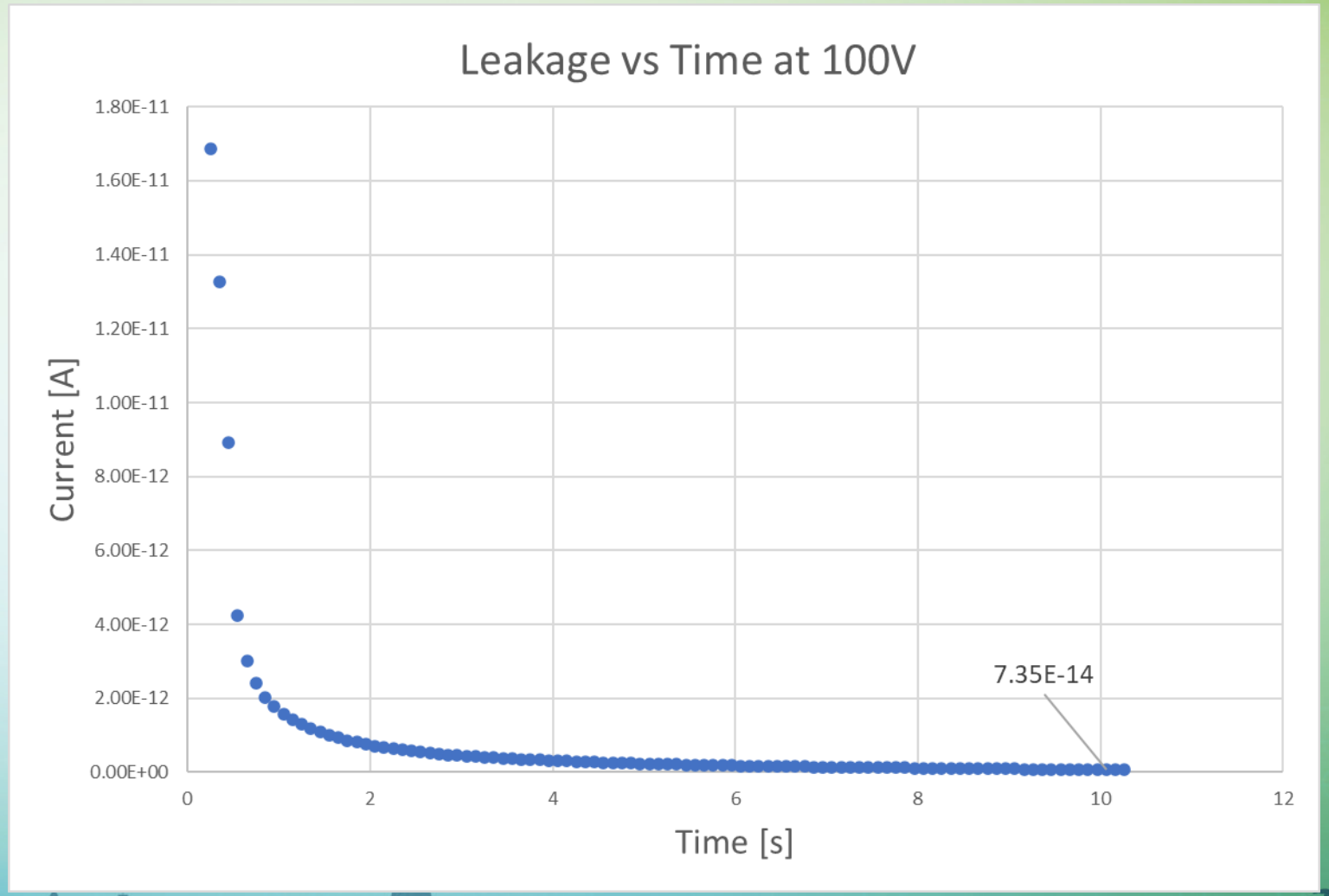
- Exceed 4 million touchdowns
- Scrub marks <50% of pad

# Test Environment

- Prober Type: TEL Precio 8
- Tester Type: Keysight 40802F Parametric
- Temp: 25C – 150C
- Test Overdrive: 50µm – 65µm
- Pad Size: 40µm
- Pad Array: 1 x 25
- Pad Pitch: 80µm
- Pad Material: Cu, Al, Pl
- Max Test Touchdowns: 10M
- Average Probe Tip Ø: 9.5µm
- Probe Material: WRe (Tungsten with 3% Rhenium)
- Probe beam Ø: 6mil

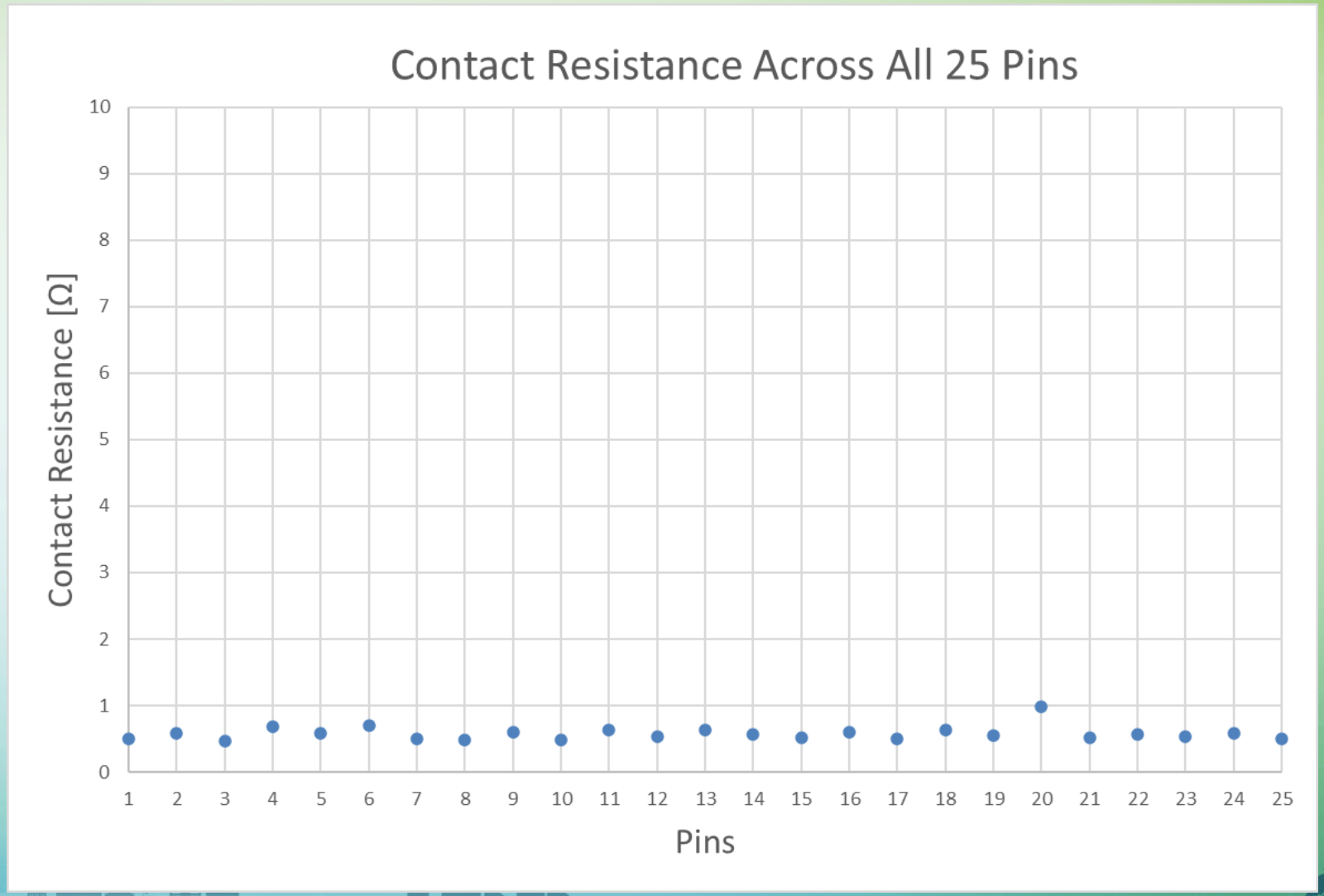
# Actual Results - Leakage

- **Average Leakage: 0.735 fA/V at 100V in 10 seconds**
  - OR
- **73.5 fA**
  - OR
- **7.35E-14 A**



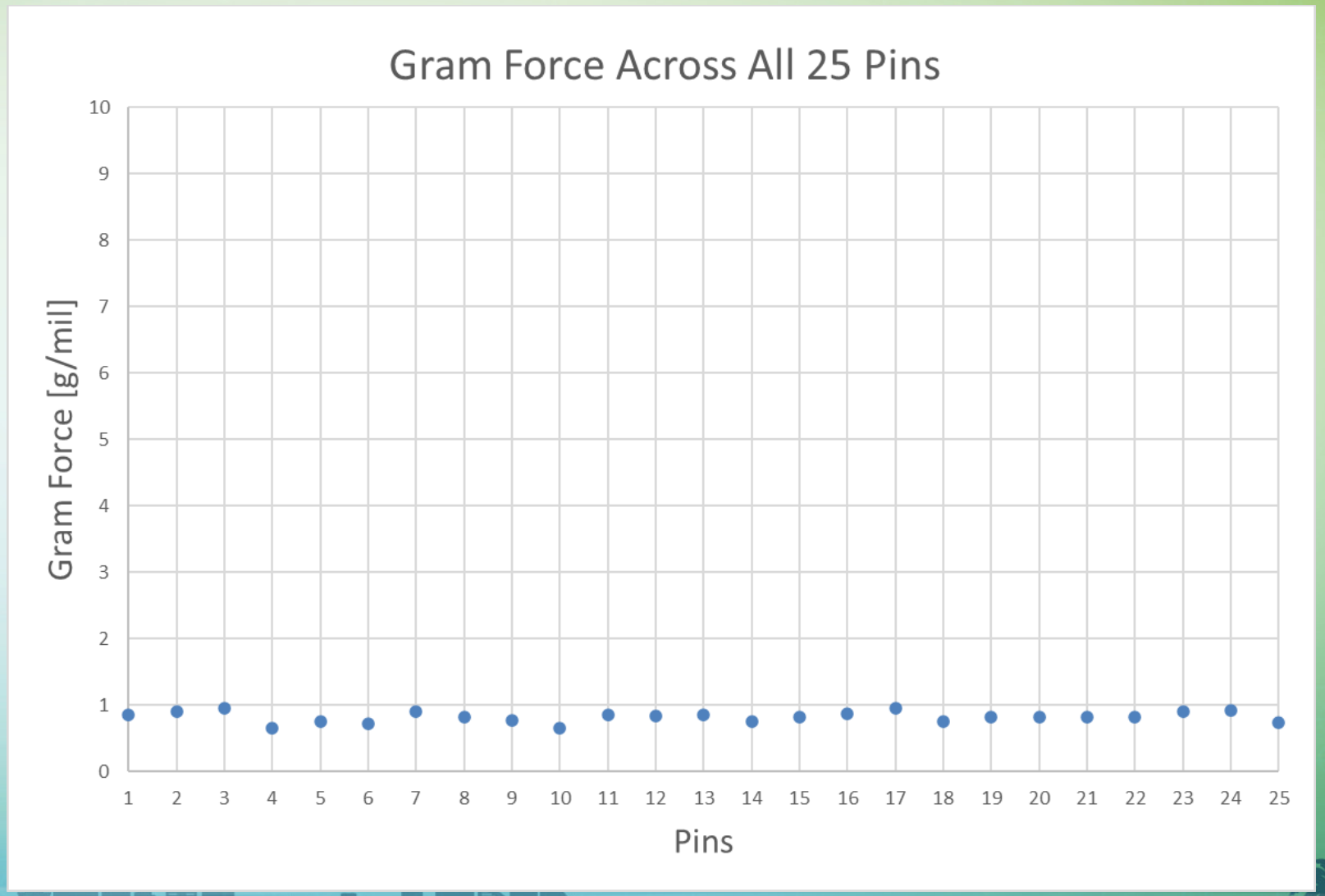
# Actual Results – Contact Resistance

- **Average Contact Resistance: 0.58Ω**



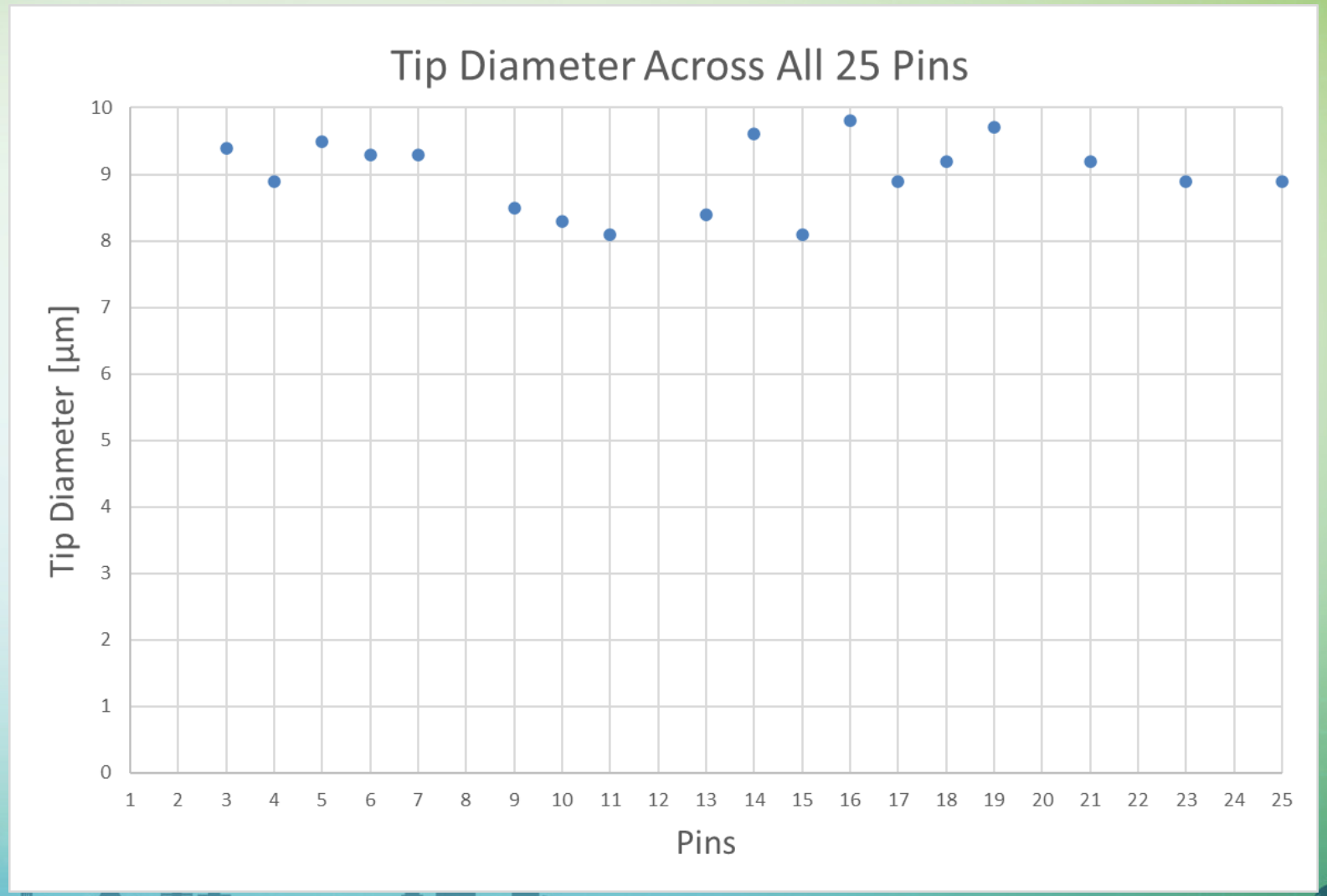
# Actual Results – Gram Force

- **Average Gram Force: 0.82 g/mil**



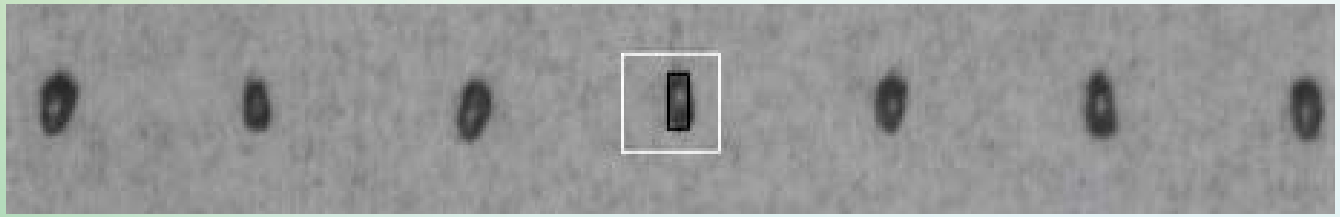
# Actual Results – Tip Diameter

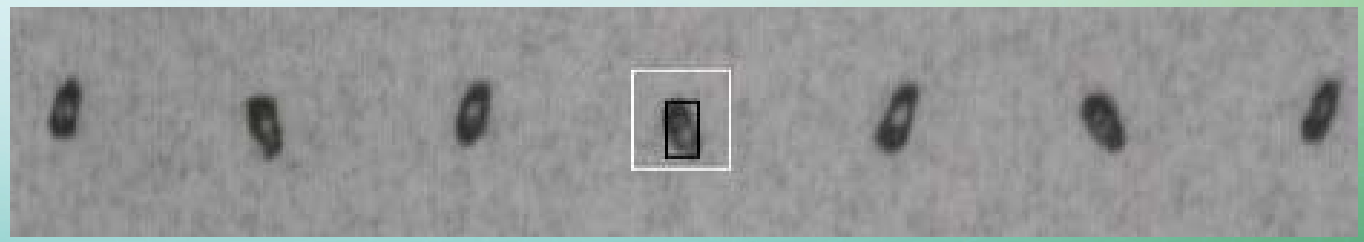
- **Average Tip Diameter: 9.5µm**



# Actual Results – Touchdowns & Scrub Marks

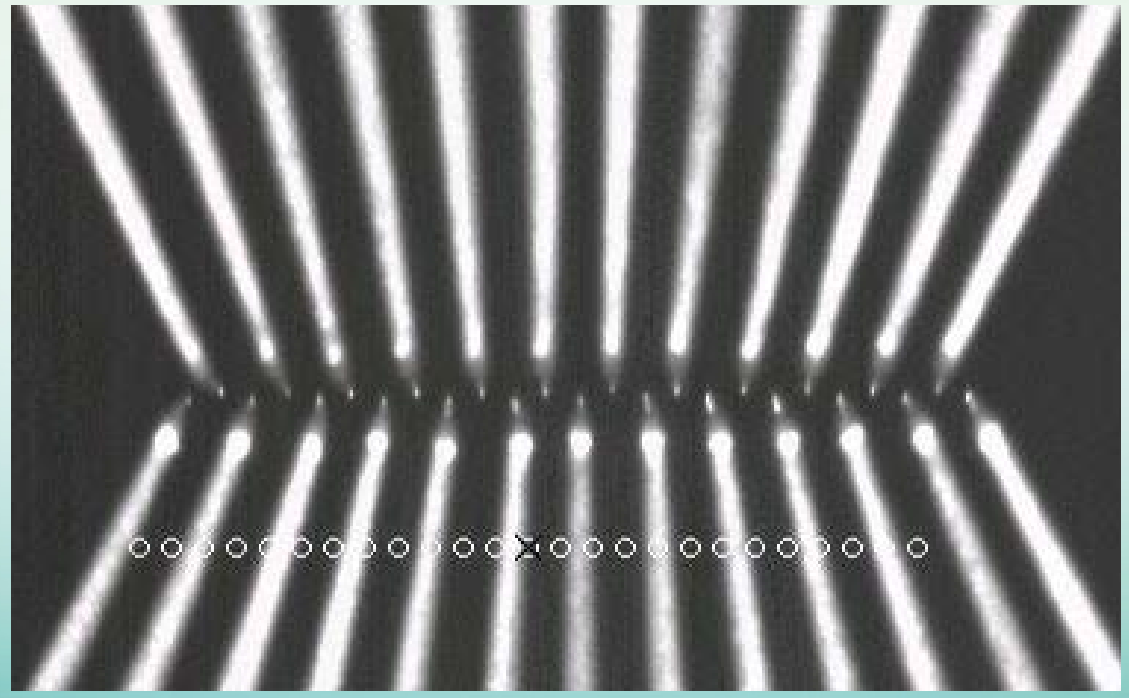
- **5-10 million touchdowns on all cards**
  - Some up to 16M+
  - Average scrub size: 18.1µm





# Actual Results - Summary

- **Incredibly Low Wear**
- **Exceptionally Long Life (12-16 million touchdowns)**



# Summary of Qualification

- **Why was Celadon chosen?**
  - To meet and exceed specifications while lowering overall cost of test
- **Results—successfully qualified**
  - All required specifications were met
- **Established regular team meetings**
  - To remain in contact on a regular basis and stay on top of any issues that may come up
- **Performance was monitored closely by the team**

# Why Such Long Life?

## Advanced Cantilever Technology

PROBE PROFILING

ROBUSTNESS

OPTIMIZED PROBE CLEANING

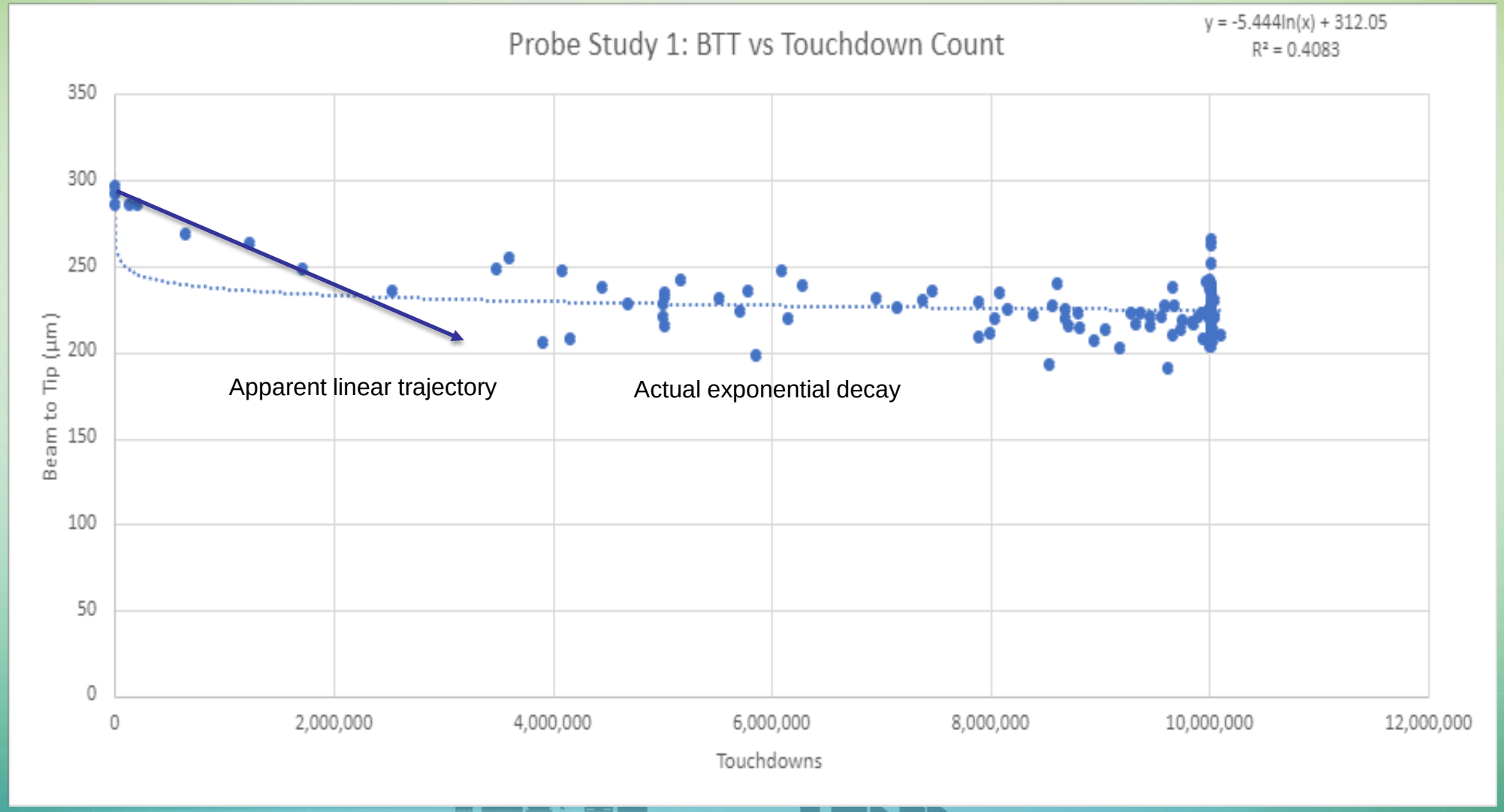
# Probe Profiling & Lifetime Analysis

Celadon probes are tapered and conditioned, leading to a more stable, exponential decay as opposed to linear

This allows us to achieve a longer lasting probe, leading to a longer overall lifetime

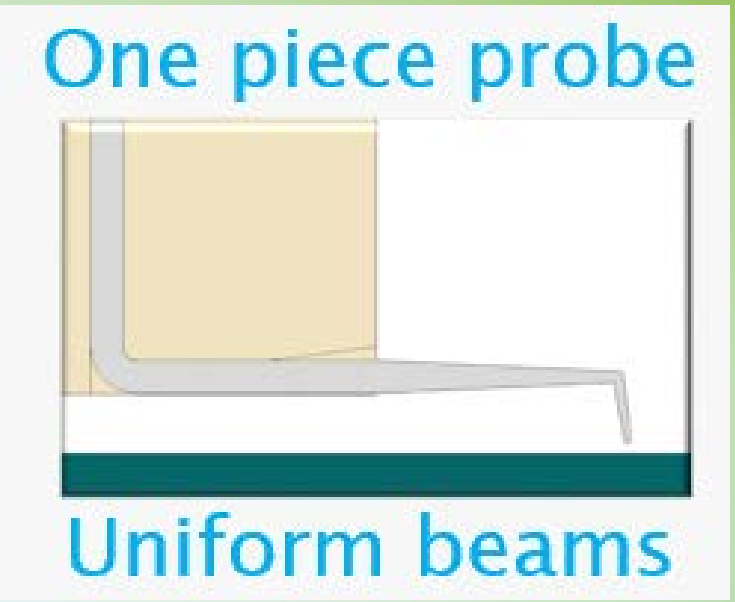
The following touchdown data was received from our customers over 2-3 years. BTT is how we classify probe toe length.

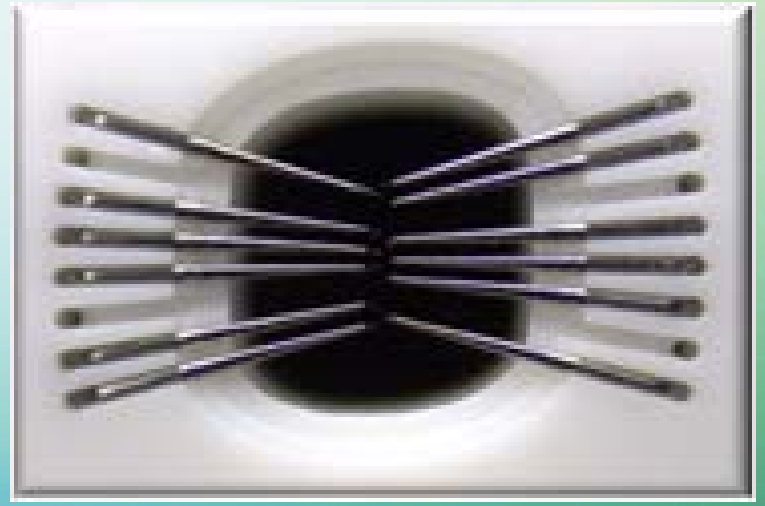
# Probe Profiling & Lifetime Analysis



# Robustness

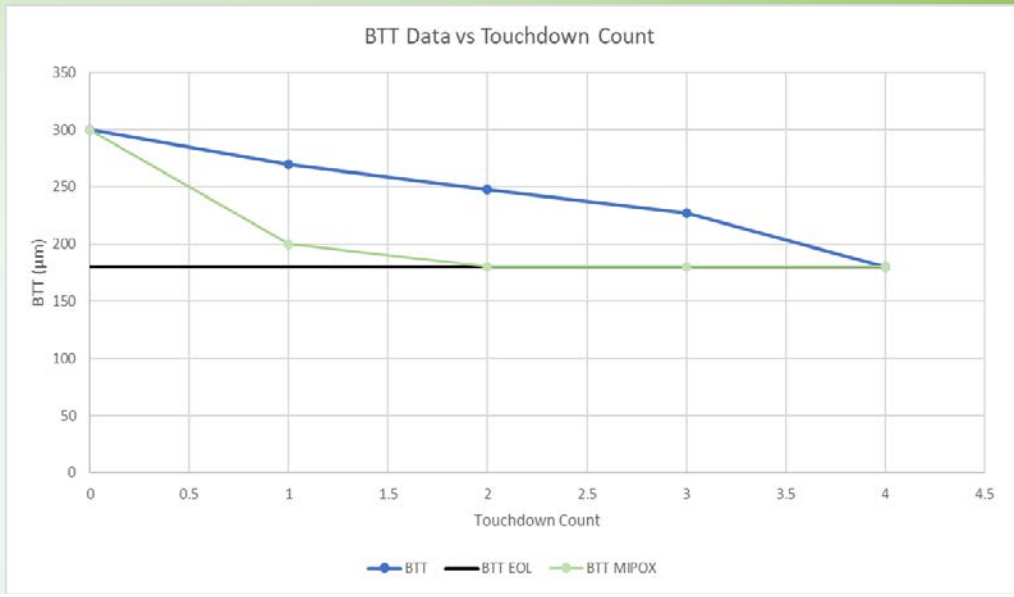
- ***Tunable gram force based on cantilever length, toe angle, and probe material***
  - Can be intentionally reduced to prevent cracking for active circuits under the pad or low K dielectrics
  - Can also be increased for scrubbing through oxide layers
- ***Mechanical Stability, Probe in Ceramic***
  - Probe is cradled in precision milled groove
  - Crash resistant
  - Precise alignment and planarity
- ***Electrical probe to pad interaction***
  - Low contact resistance due to predictable scrubbing
  - Low noise, low leakage, fast settling

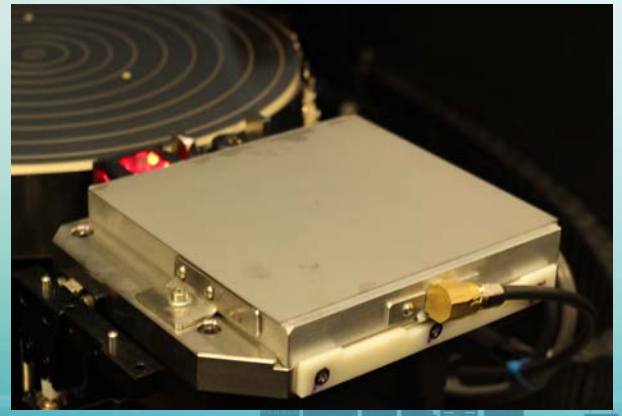


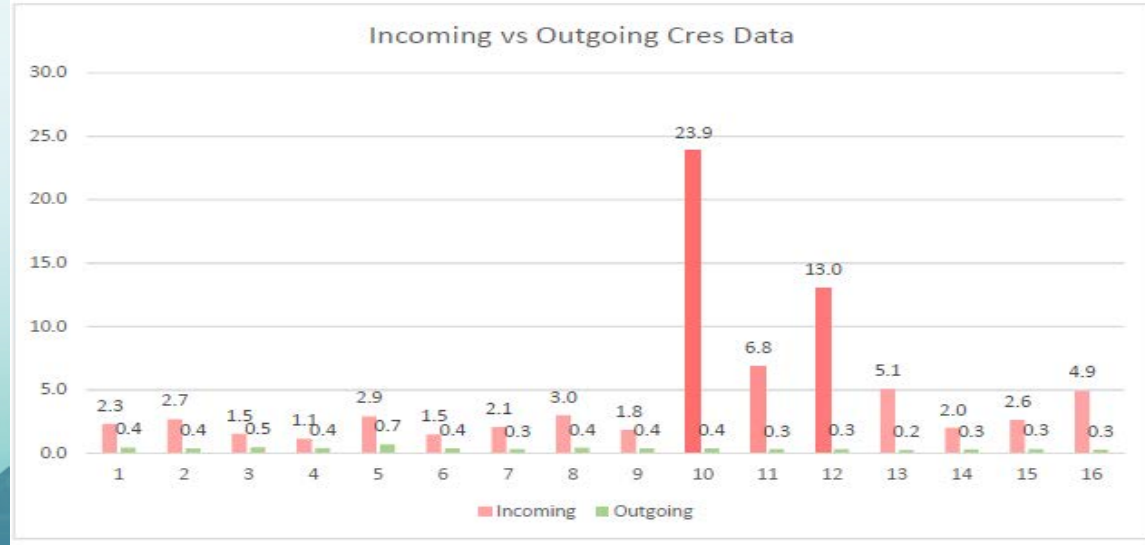



# Cleaning & Maintenance

- **ITS PP99**
  - Can improve Cres
  - Cleans away debris from tip
  - Decreases Tip Ø (sharpens)
  - Does **not** decrease BTT
- **CWC (Celadon Tungsten Carbide)**
  - Improve Cres
  - Removes embedded particles
  - Increases Tip Ø (flattens)
  - Decreases BTT
- **Soft Bristled Brush**
  - Cleans away loose debris
  - Might **not** cure Cres issue (will not remove imbedded particles)





# Decision to Automatically Rebuild

Exceptional lifetime performance of the VC20™ prompted regularly scheduled customer focus team meetings to decide to prematurely rebuild probe cards between 8-10 million touchdowns.

The automatic rebuild program mitigates the risk for unplanned failure on the fab floor

Without unplanned failure, the fab floor runs smoothly and predictably

# Consequences of Unplanned Failure

PROBER/TESTER SITS IDLE

REQUIRES SPARE CARDS

HANDLING INFRASTRUCTURE

PULLING/REPLACING INVENTORY

# Benefits of no Unplanned Failures

FLOOR RUNS SMOOTHLY

PREDICTABILITY OF PRODUCTION SCHEDULE

SIMPLIFY PLANNING FOR PURCHASING & BUDGETING

LOWER TOTAL COST OF OWNERSHIP (TCO)

# Overview of Total Cost of Ownership (TCO) Model

- **Purpose**
  - To understand cost, failures, lifetime performance
  - To compare Celadon with other products & technologies
- **In the TCO Model, the green fields are changeable**
  - All pricing (Celadon's and Competitors')
  - Labor rates
  - Services
  - Quantity of spares

# Overview of Total Cost of Ownership Model

- **Final Notes**
  - Breakeven points are clearly visible
  - Bar graph showing cost per touchdown comparing each probe card technology
  - Both 8 million and 10 million rebuild calculations
  - This model can be made available upon request

# TCO Model Example

Inputs

| | Product | Cost Per Unit | Shipping | Total Cost | Labor Cost/hour: | |
|---|---|---|---|---|---|---|
| Hardware Cost | VC20 Core | [redacted] | [redacted] | [redacted] | Number of testers: | 25 |
| | Motherboard | [redacted] | [redacted] | [redacted] | VC20 cards required per tester: | 1.2 |
| | Celadon Aligner | [redacted] | [redacted] | [redacted] | <--only included in Tier 2 calculation | |
| | Celadon Analyzer | [redacted] | [redacted] | [redacted] | <--not included in any calculations | |
| | MEMS Probe Card | [redacted] | [redacted] | [redacted] | MEMS cards required per tester | 1.15 |
| | Epoxy Ring Card | [redacted] | [redacted] | [redacted] | | |
| | Epoxy Ring Card Rebuild (shipping included) every 250K TD | [redacted] | [redacted] | [redacted] | Epoxy Ring cards required per tester: | 4 |

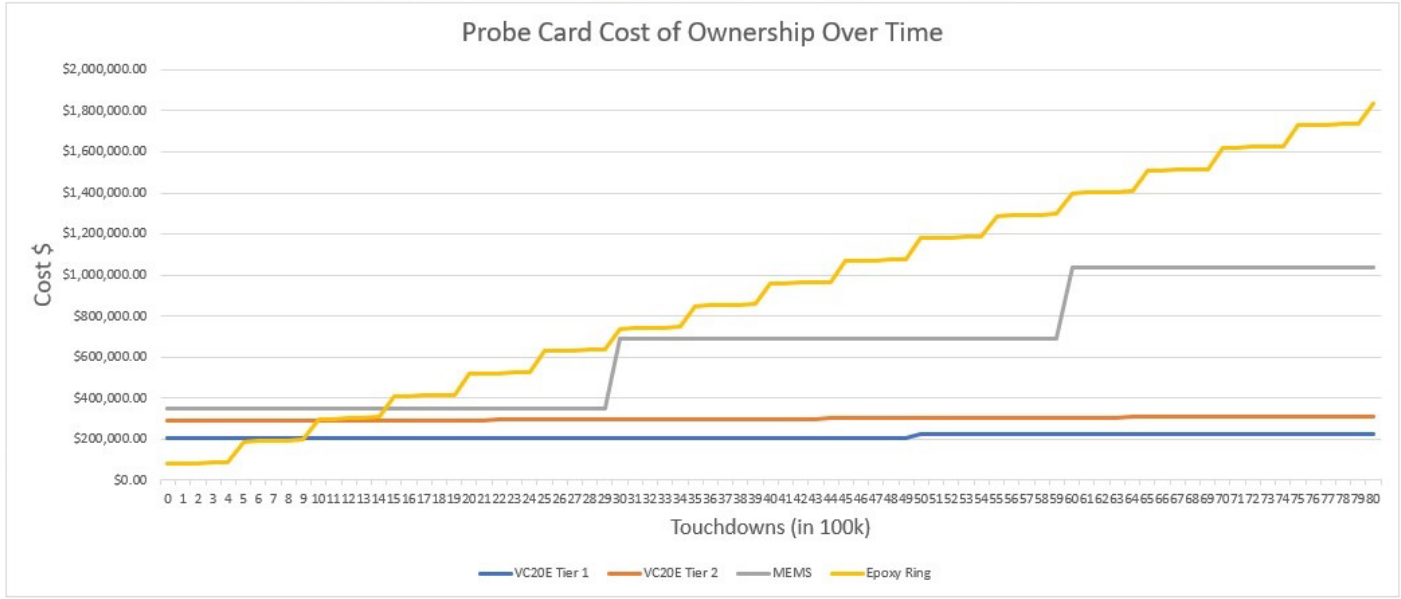
| | Item | Time Offline (hrs) | Cost per | Labor Estimate | Total Cost |
|---|---|---|---|---|---|
| Offline Cost | ACT at 5M | [redacted] | [redacted] | [redacted] | [redacted] |
| | Minor Adjust every 200k | [redacted] | [redacted] | [redacted] | [redacted] |
| | VC20E Rebuild | [redacted] | [redacted] | [redacted] | [redacted] |
| | Epoxy Ring PM every 50k | [redacted] | [redacted] | [redacted] | [redacted] |

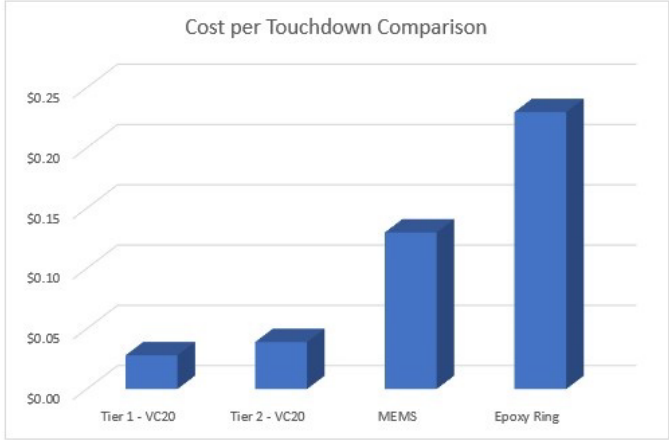
Note: VC20E Tier 1 and Tier 2 refer to the same product; Tier 1 does NOT include the cost of an aligner, where Tier 2 does

| VC20E Lifetime Cost as a % of Competitor Cost | | |
|---|---|---|
| | Tier 1 | Tier 2 |
| MEMS | 21.60% | 30.06% |
| Epoxy Ring | 12.21% | 17.00% |
| | *Tier 1 - VC20: No Aligner* | *Tier 2 - VC20: Aligner included* |

| Cost per TD | |
|---|---|
| Tier 1 - VC20 | $0.03 |
| Tier 2 - VC20 | $0.04 |
| MEMS | $0.13 |
| Epoxy Ring | $0.23 |

CELADON™
THE HOME OF PEACE OF MIND PROBING




NOTE: Pricing does not reflect GF pricing structure, and has been redacted for confidentiality purposes

# Conclusion

We successfully qualified our VC20E probe cards with Global Foundries Malta

The Total Cost of Ownership model has become an essential tool for aiding our customers in choosing the best probing partner for their floor.

This tool coupled with the automatic rebuild program at 8-10 million touch downs has resulted in a very predicable probing process and an efficient probe floor for our customers.

# What's next?

| | |
|---|---|
| Monitor | Monitor performance of our VC20E cards at Global Foundries |
| Broaden | Broaden TCO Model to include more Celadon products and other probe card technologies |
| Fine Tune | Fine tune our TCO Model as we learn more from our partners |
| Continue | Continue collecting TD data measurements to further improve the lifetime extrapolation and analysis graphs |

# Credits/Acknowledgement


- Jacqueleen Ngo-Hatchie, Global Foundries
- Garrett Tranquillo, Celadon Systems