Dangelmayer ASSOCIATES, L.L.C.
Trusted ESD Programs Since 1978

Class 0 & Reliability
ESD Case Studies

Professional Services Only
No Product Sales!

- ***Client Locations***

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ESD CLASS ZERO APPROVED™

Examples of Customer Base

Outline

- Preliminaries
- Manufacturing Quality Case Studies
- Reliability Case Studies
- System Reliability Case Studies
- Class 0 Case Studies

ESD Acronyms

- EPM:
  - ESD Program Management:
    A Total EPM Quality System

- EPM Yield Risk Benchmarking™
  - Relative Compliance to Best Practices
  - Quantifies Yield Improvement Opportunity

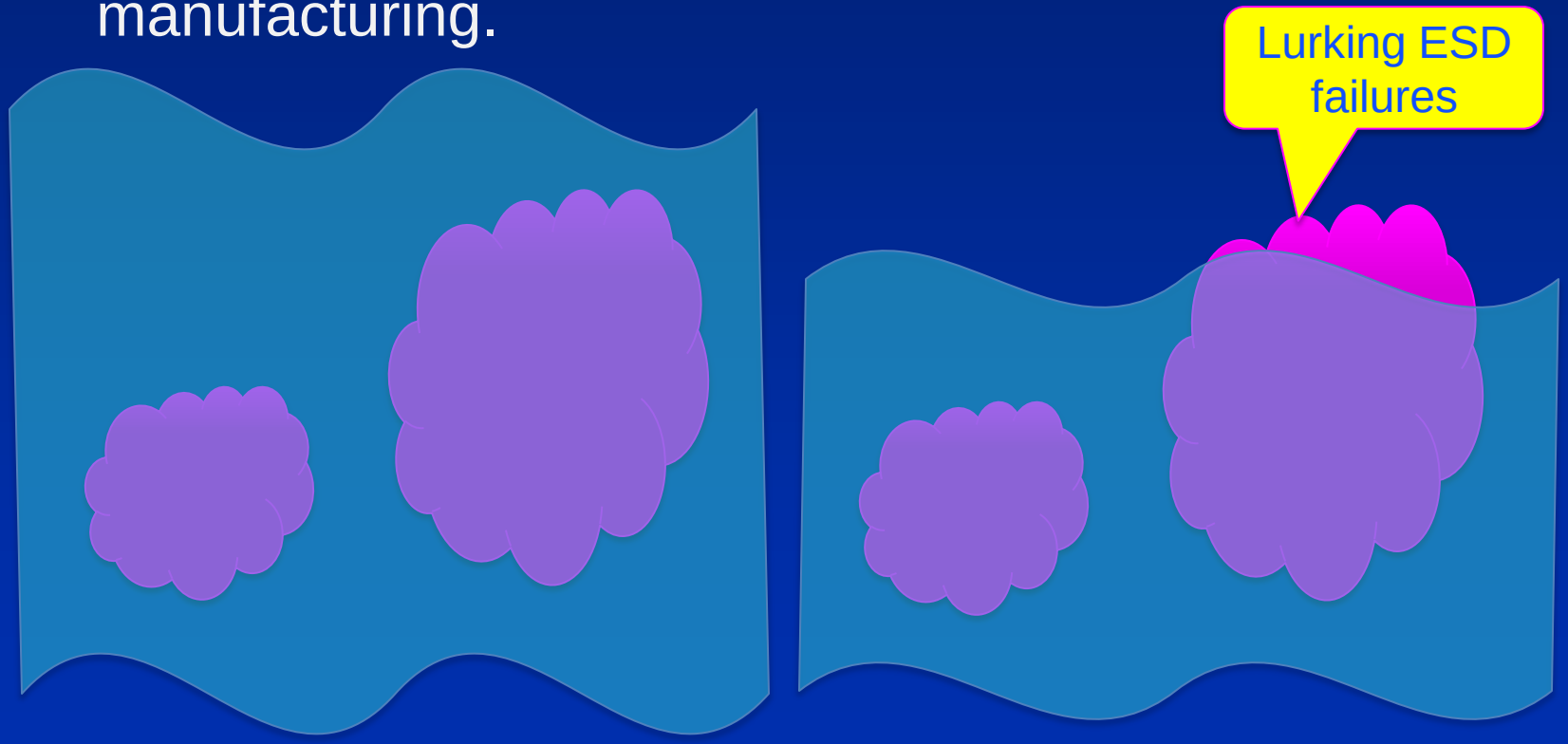
- HBM – Human Body Model
- CDM – Charged Device Model
- CBE – Charged Board Event
- CDE – Cable Discharge Event
- EOS – Electrical Overstress
  - IC Damage due to Electrical Over Voltage or Current

"Class 0" Terms Used in this Tutorial

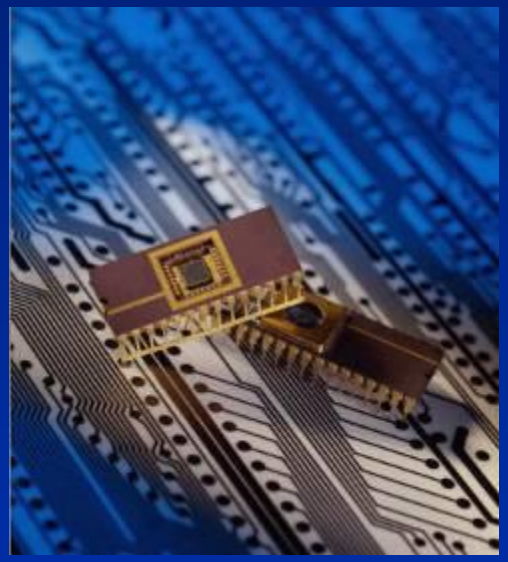
- Class 0
  - Blanket term used to refer to devices with thresholds less than 250 volts HBM or CDM (i.e., Class OA or OB)
- Class 0B
  - Withstand Voltage greater than/equal to 125 volts and less than 250 volts HBM or CDM
- Class 0A
  - Withstand Voltages Less than 125 volts HBM or CDM
- Class "000"
  - Withstand voltage Less than 50 volts

Class 0 Exposes Issues

- Lower water level exposes boulders in a stream.
- Class 000 exposes CDM issues in sensitive device manufacturing.



ESD Damage
A Quality & Reliability Issue



- **Catastrophic**
  - **Device failure that is both sudden and complete. It involves complete loss of the required function**
- **Cumulative**
  - **Device failure resulting from multiple sub-threshold exposures to ESD**
- **Latent**
  - **Device failure over time due to prior ESD damage**

Class 0 Risk Technologies

- ICs
  - Nanoscale CMOS
  - RF
  - GaAs
- Optoelectronics
  - Lasers
  - LEDs
  - Detectors (PIN, APD)
- MEMS
- MR Heads

Sylvania Application Notes

ESDA Technology Roadmap
Device Thresholds Are Declining

	Average Device Thresholds								
Model	**1975**	**1982**	**1985**	**1992**	**1998**	**2003**	**2007**	**2013**	**2014**
HBM	**900V**	**1400V**	**2800V**	**3800V**	**3000V**	**2200V**	**1500V**	**1000V**	**750V**
CDM	**275V**	**285V**	**750V**	**800V**	**700V**	**675V**	**625V**	**325V**	**240V**

IC Design Target Levels

Model	2009	2010
HBM	**2000V**	**1000V**
CDM	**500V**	**250V**

Manufacturing Quality Case Studies

Aerospace Manufacturing Case Study
CDM Device Failures

Background

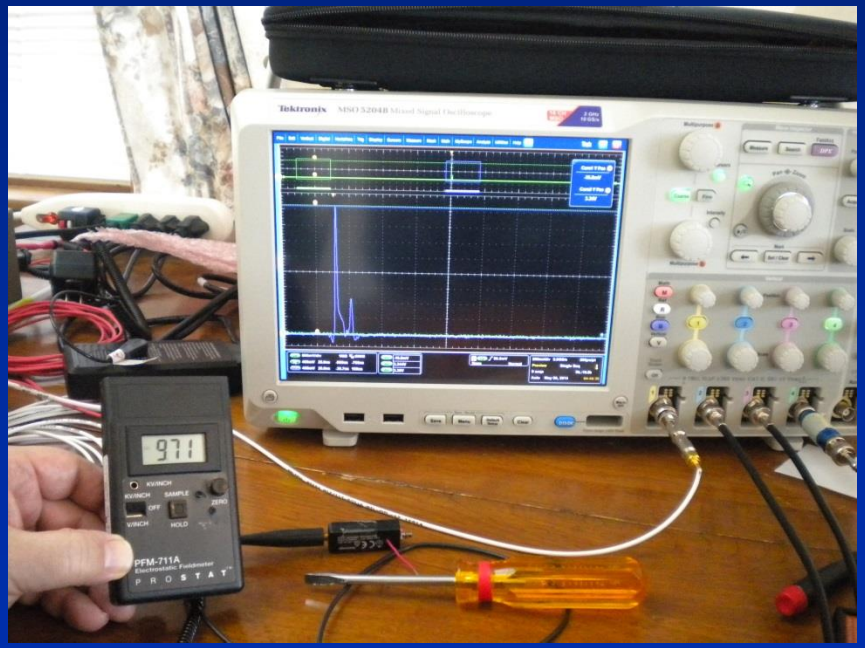
- **No Prior History of ESD Failures**
- **Multiple CDM Failures Detected**
- **Triggered Extensive Investigation**
  - **All Manufacturing Locations**
  - **Factory Programs Based on HBM**
- **Identification and Resolution of Root Cause Major Concern**

Aerospace Manufacturing Case Study
CDM Device Failures

Root Cause of Factory Failures

- Military ESD Requirements 40 Years Out Dated
  - Minimal CDM Controls In Place
- Compliance Verification Inadequate
- Charged Screwdriver
  - Used At Multiple Manufacturing Sites
  - Generated Discharge Currents up to 6.7 Amps!!!

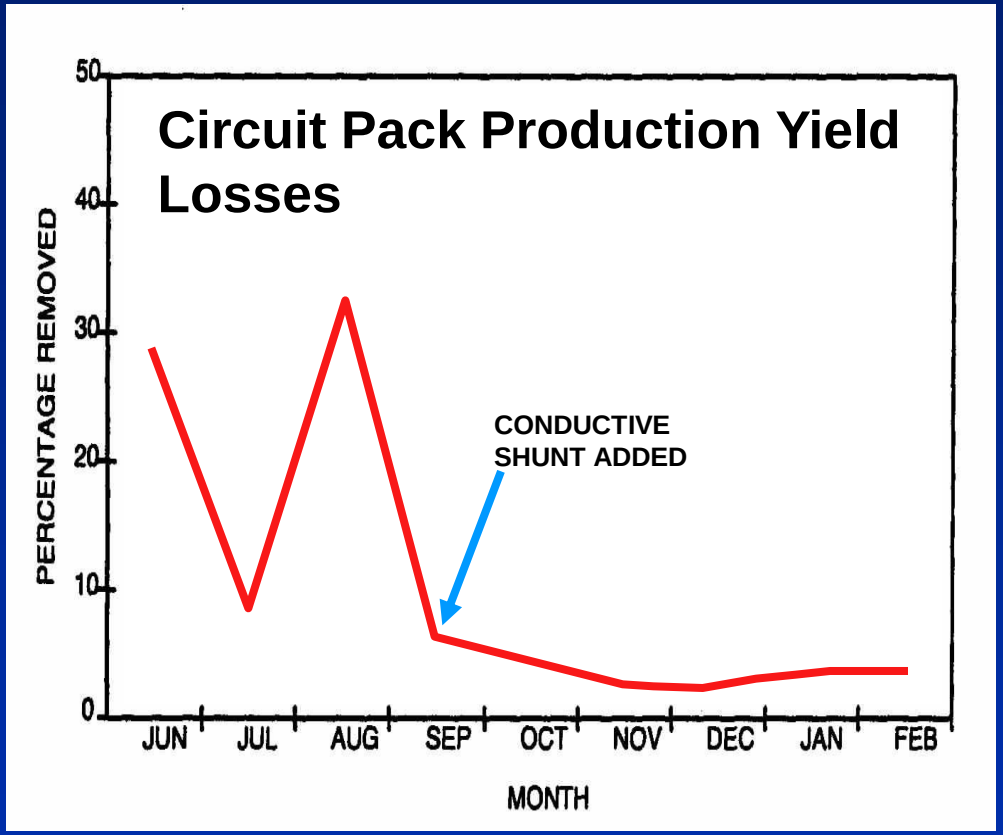
Screwdriver Discharge Current Test – 6.7 Amps



Customized Solutions Are Essential

Circuit Board - Class 000 Case Study:

- Design Transfer
  - No ESD Data
- 15 Volt CDM Threshold
- 100% Failure Rate: Some Lots
- $1.2B Sales Jeopardy
- $1K Invested in Shunt
- $6.2M/yr Savings Documented

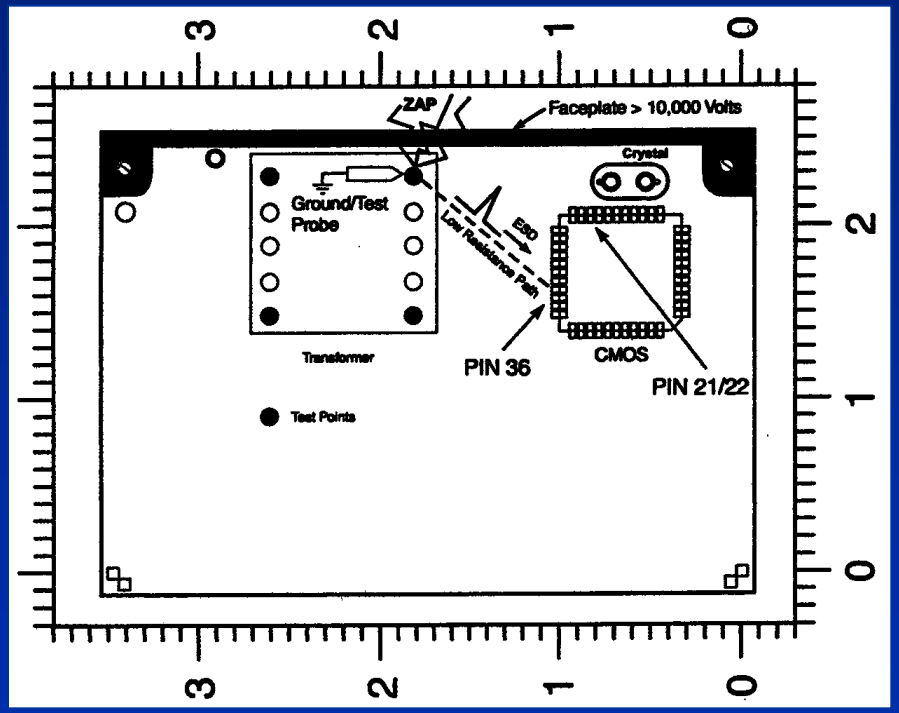


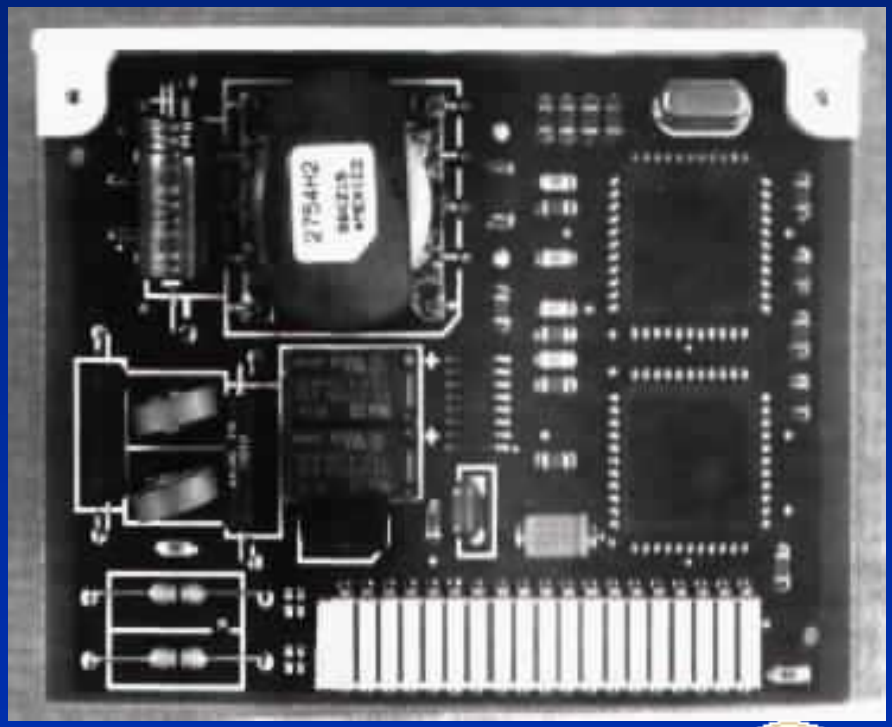
Book: ESD PROGRAM MANAGEMENT
Ted Dangelmayer

Faceplate Field- Induced CBE Failure

Established Code - New Faceplate Supplier

40% Failure Rate - 1.5KV CDM Threshold





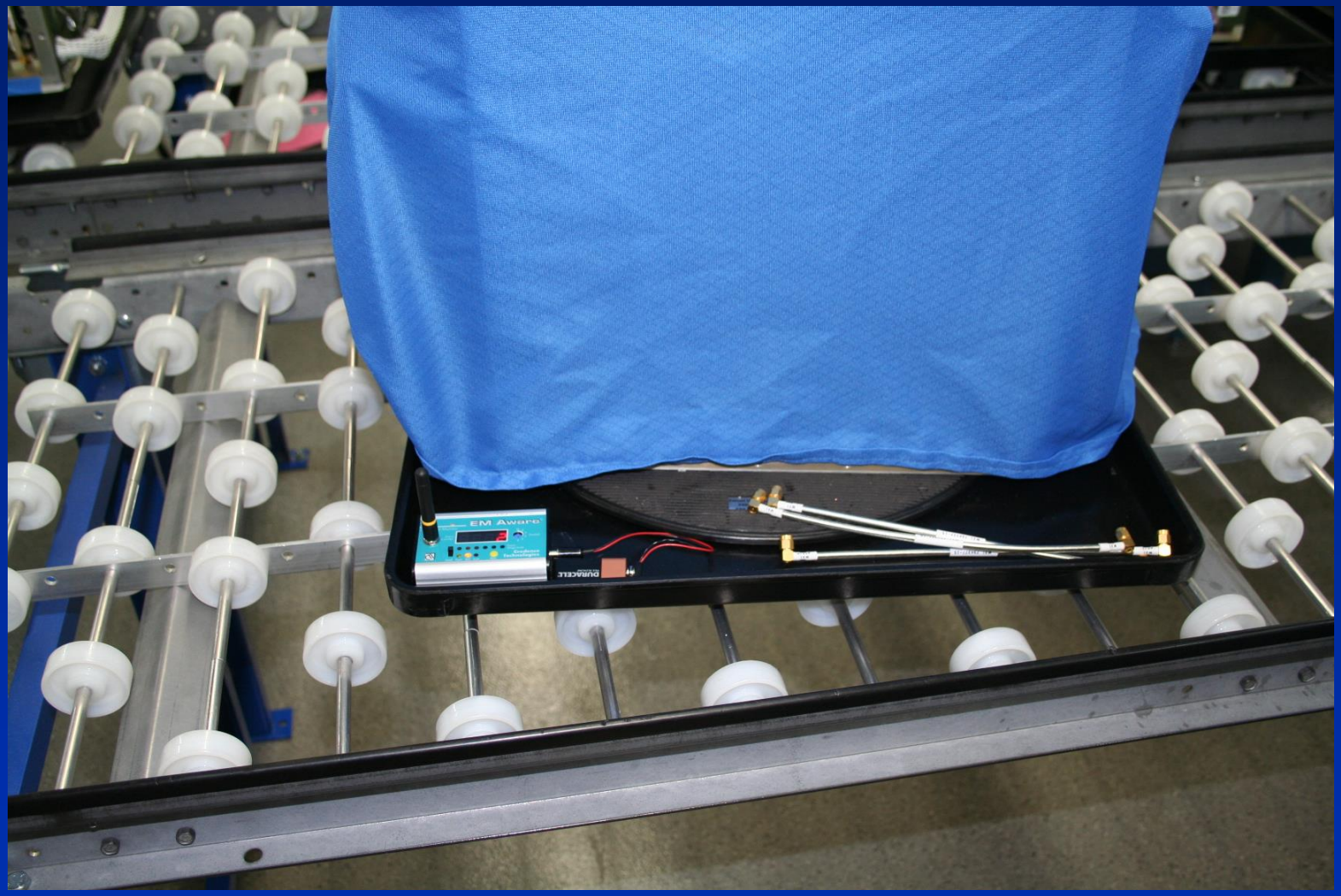
Ref: ESD Program Management, 2nd edition, pp59-61

Defense Manufacturing: EOS (CBE/CDE) Case Study

- Background - Subsystem Assembly Operation
  - 12% Circuit Board EOS Failure Rates
  - FA Determination by IC Supplier was EOS
  - Ungrounded Conveyor System
  - Static Generating Carts
  - Strong & Persistent ESD Discharge Events
    - During Assembly Operations
    - Installing Coax Cables
- ESD CBE & CDE Countermeasures Reduced Failures by 80%

Strong ESD Events During Assembly

Charged Product and Cables



Class 000 – Wafer Saw Example Unexpected Results!

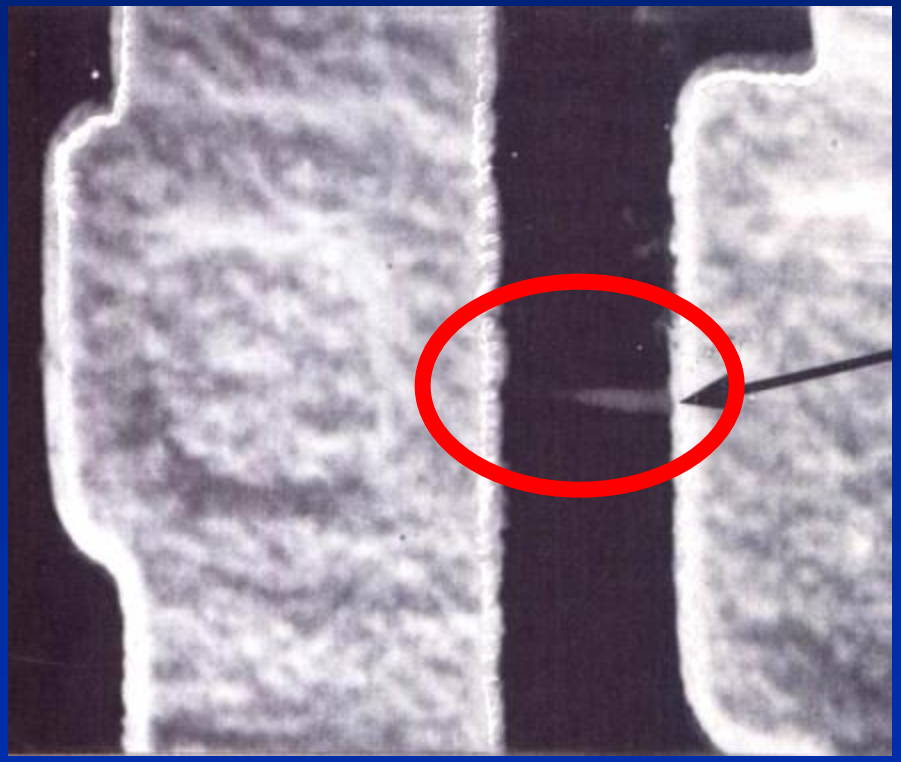
- CDM Threshold – 35 Volts
- 92.2% Defective at Wafer Saw
- Failure Analysis
  - CDM Damage

Reliability Case Studies

ESD Latent Damage
A Quality & Reliability Issue

- Bipolar Junction
- 450 Volt HBM Withstand Voltage
- 3 of 15 Failed QA Tests
- 5 of 24 Circuit Boards Failed after Five Days
- Customer Failures: 17 of 31 Circuit Boards Failed after two Weeks

Latent Failure

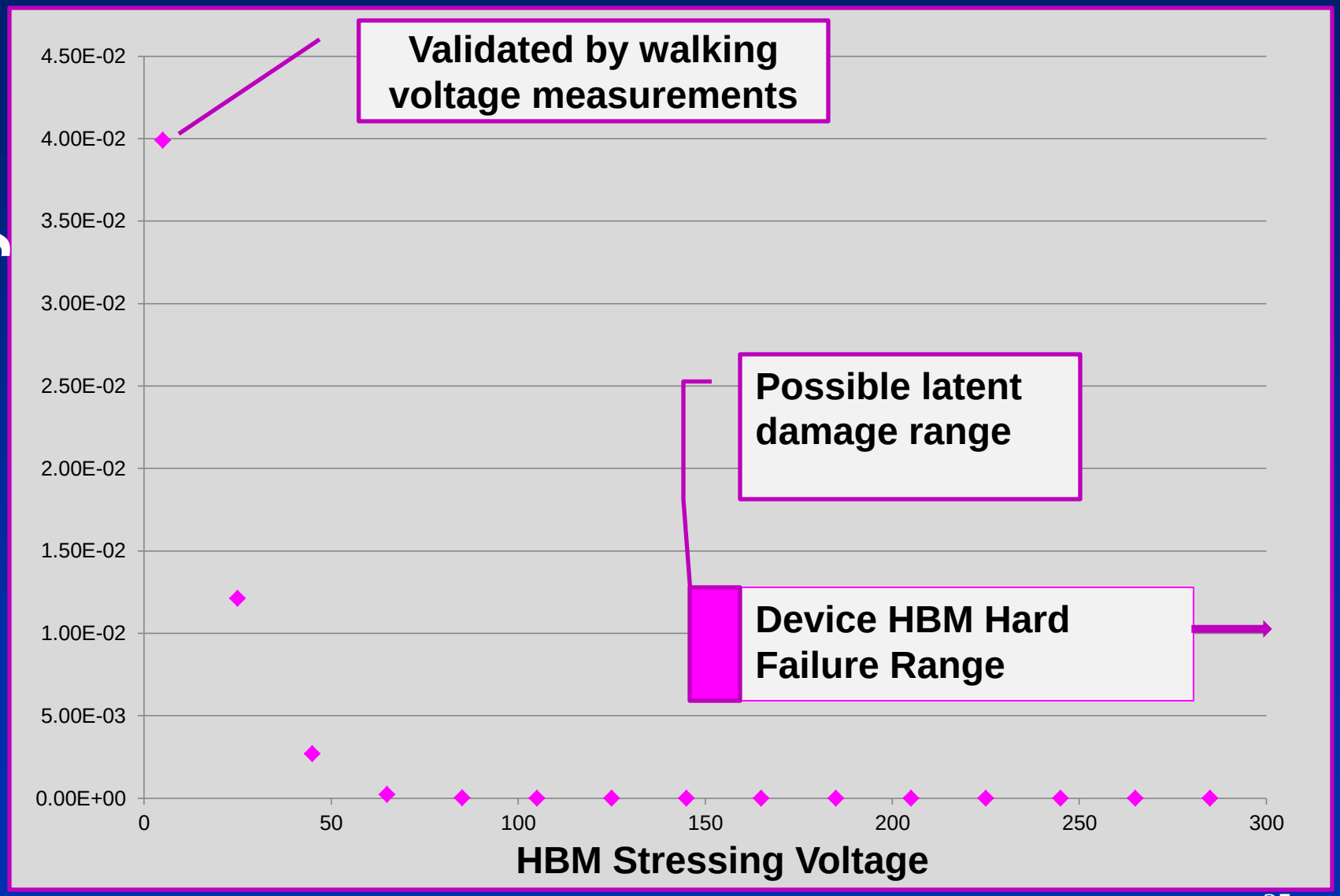


Defense Manufacturing Case Study
Device Classification Error

Background

- **MOSFET Device Reclassified as Class 0 - HBM**
- **Triggered Extensive Investigation**
  - **All Manufacturing Locations**
- **Latency Major Concern**
  - **Analysis Indicated Latency Risk Not Significant**
    - **For HBM**

HBM Voltage Distribution with Basic S20.20 Controls in Place

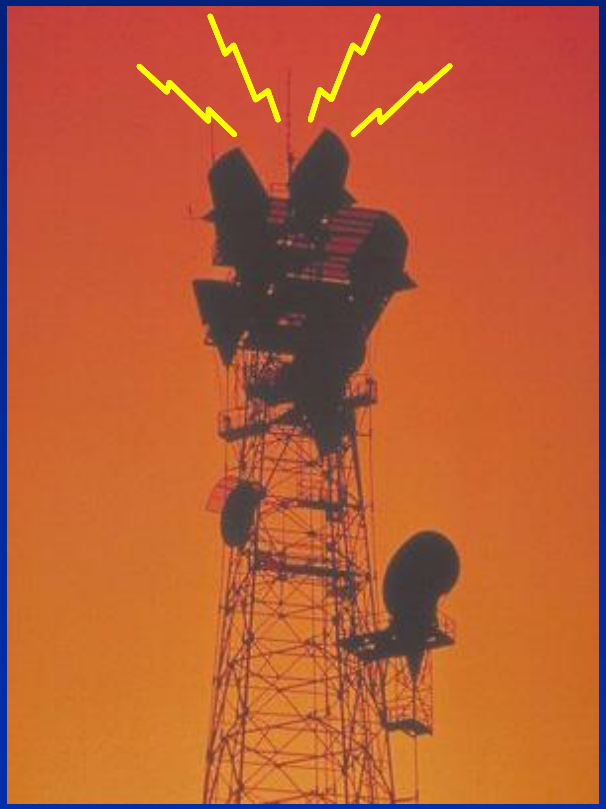


System Reliability

System Level ESD Upsets

ESD Generates Radio Waves That Affect Microprocessors

- **Scrambled Program Instructions and Data**
- **Microprocessor Lockup**
- **Confusing Error Messages**
- **“Software Errors”**



Product Design Reliability Case Study: Lightwave Transmission System

- Multi-million Dollar Lightwave System
- No Design Transfer Verification Of ESD/EMI Protection
- Three Years Apparently Successful Deployment
  - Then:
    - Major Alarms
    - Customer Complaints
      - Major Alarms W/O Direct Equipment Contact
      - Forced To Remove Bays
      - 1 $B Lost Sales

Medical Reliability – System Level Case Study: Tinnitus Treatment Device

Background

- Failures In The Field And Lab
- Production Stopped!
- Test Methods
  - Electrostatic Tribocharging
  - ESD When Plugging Headphones Into Charged Unit
  - Measuring Current When Plugging In Headphones
  - EMI Susceptibility Using ESD Gun
    - Failure Level Increase With Ferrite Core
  - ESD/EMI Susceptibility With Power Cord
  - ESD Gun To Metal On Headphones
  - Staticide Treatment Of Plastics

Medical Reliability – System Level Case Study: Tinnitus Treatment Device

Summary of problems found

- ESD: severe tribocharging of plastic body combined with metal contact when plugging in headphones results in critically severe ESD event that upsets unit
- ESD: Spark to metallic part of headphones upsets unit
- EMI Susceptibility: headphones act as an antenna that picks up radiation from nearby spark and upsets internal circuitry
- Processor is susceptible to ESD/EMI upset 100% of the time, because it is never really turned off. This is highly undesirable from an ESD/EMI susceptibility point of view
- ESD testing degraded performance of protection devices

Medical Reliability – System Level Case Study: Tinnitus Treatment Device

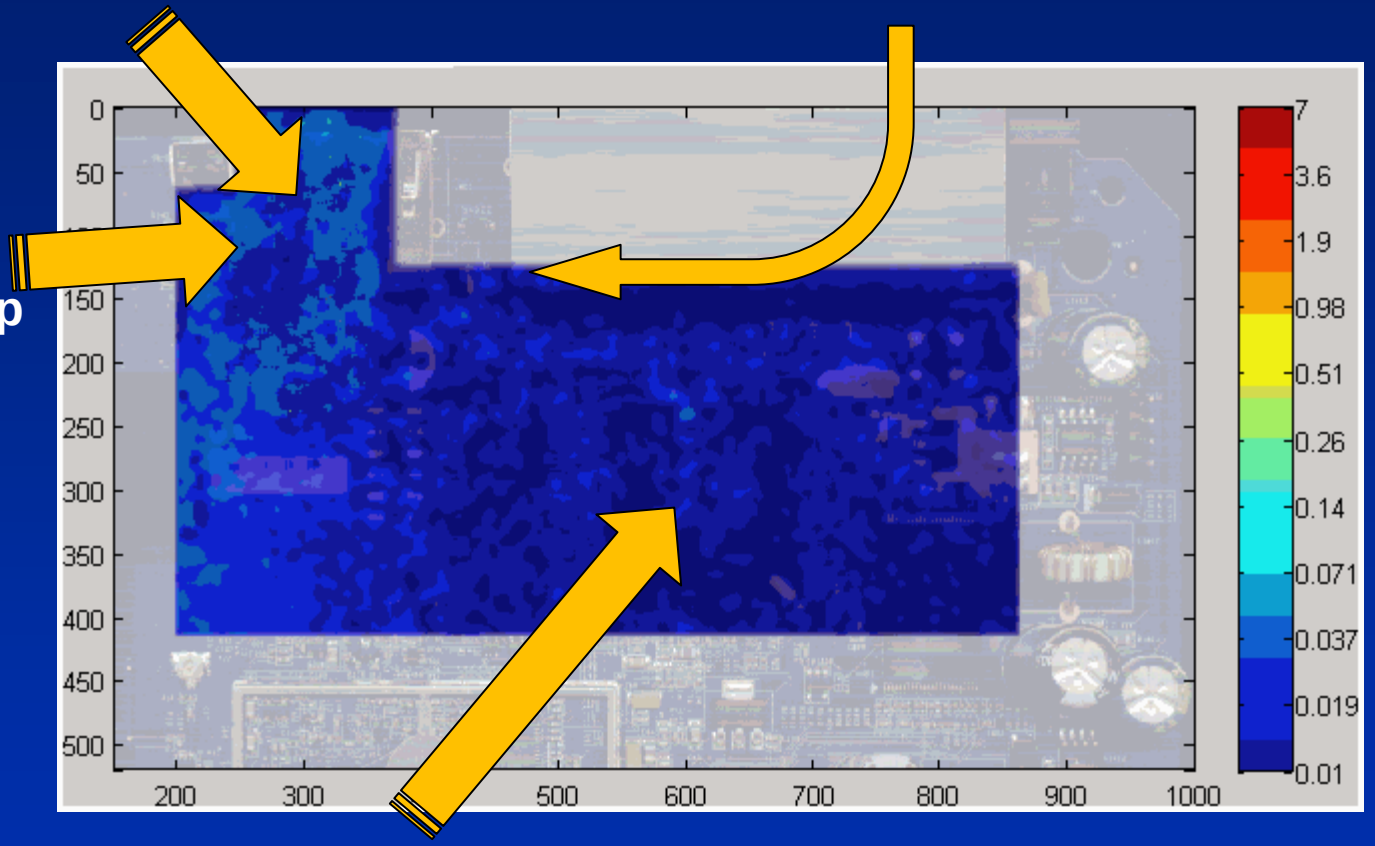
Solutions

- Product Design Changes
  - Reduce tribocharging of unit to safe level
  - Prevent ESD spark from occurring between headphone and metal ring of jack
    - Static dissipative material on jack or headphone plug
  - Add impedance between headphone and VLSI IC
    - Ferrite core, series resistance or inductance
  - Shunt ESD current from headphone to ground plane of PCB
    - Diode, etc
  - Improve ESD robustness of VLSI input pins
  - Current Reconstruction Scanning Most Definitive Analysis

Example of USB strike causing Ethernet soft error…

(1) ESD pulse is injected into USB port (Units in A/m)

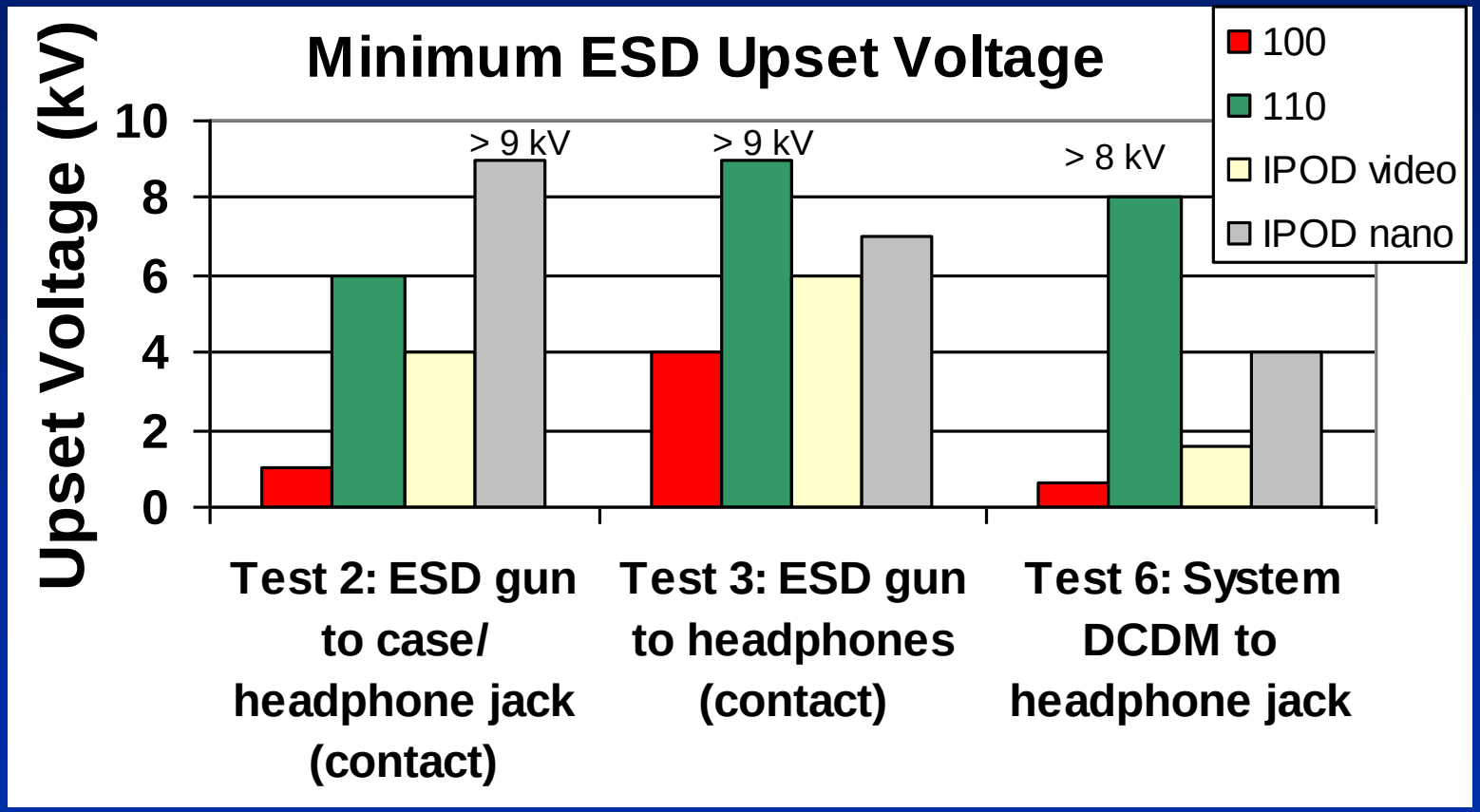
(4) Some energy coupled into nearby nodes (Ethernet port) causing upset



(2) ESD Clamp shunts majority of pulse to ground plane

(3) Residual Current shunted by clamps inside ASIC

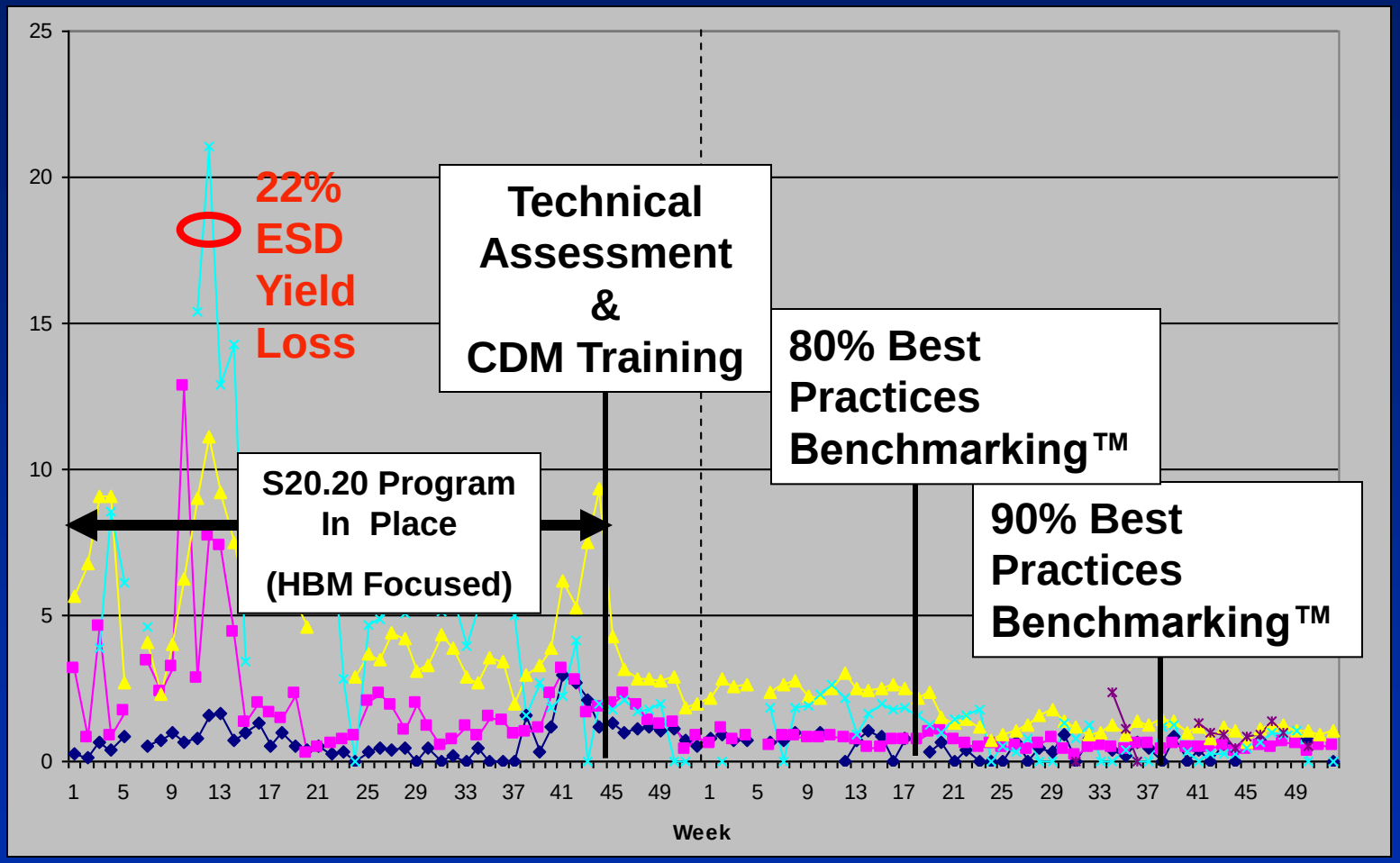
Tinnitus Unit vs. IPOD Comparison



- Significant improvements in 110 processor
- Passes Level 2 (>4kV failure level)

MR Head Class 0 Case Study

S20.20 Class 0 Limitations and Yield Improvements by Adding CDM & CDE



Note: Courtesy Herald Datanetics ltd. - 1st Class 0 Certified Manufacturing Operation http://www.dangelmayer.com/class-0-certification.php **Each data point is confirmed ESD damage during production (typically 65 volt CDM/HBM ESD sensitivity) and different colors represent different products.**

Test Equipment Review

- **Measuring Current Transients**
  - Current Probe: Tektronix CT-6 (2ghz Bandwidth)

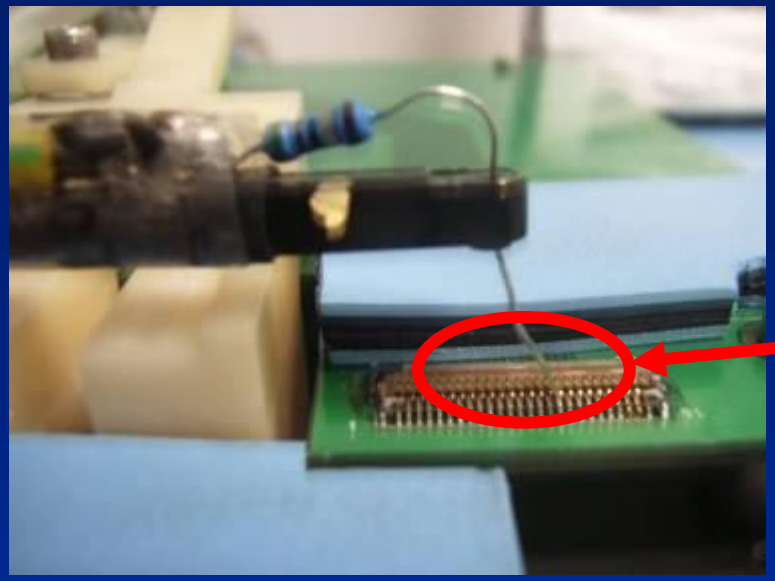
- **Measuring EMI From Sparks**
  - Credence EM Aware With Data Acquisition System

Example: Setting Maximum Acceptable V, I for Class 0A

- CDM ESD Sensitivity
  - 60 Volts
  - 100 Ma

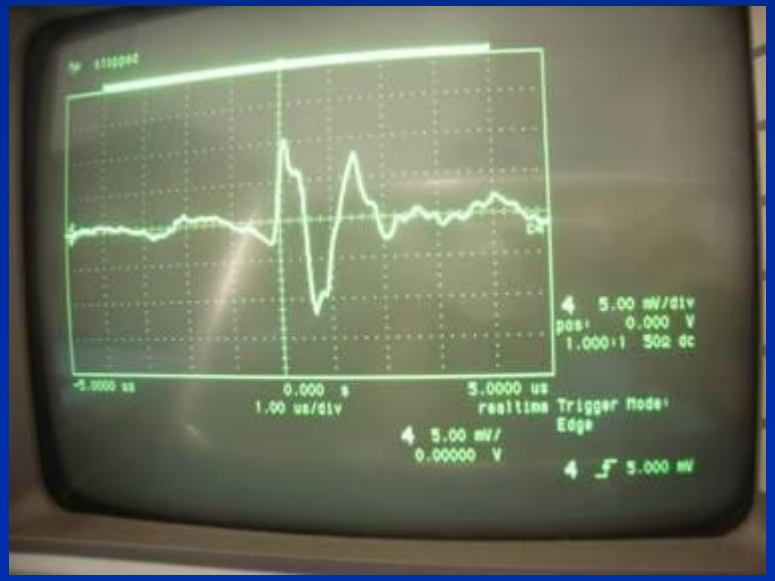
- Manufacturing Specification*(1/10th Failure Level)*
  - Current Transients: ≤ 10 Ma
  - EMI: No Event Over 6 Volts CDM

SRT Test Set Current Probe Measurement)



Connector

Continuous Contact



Maximum current: 2mA

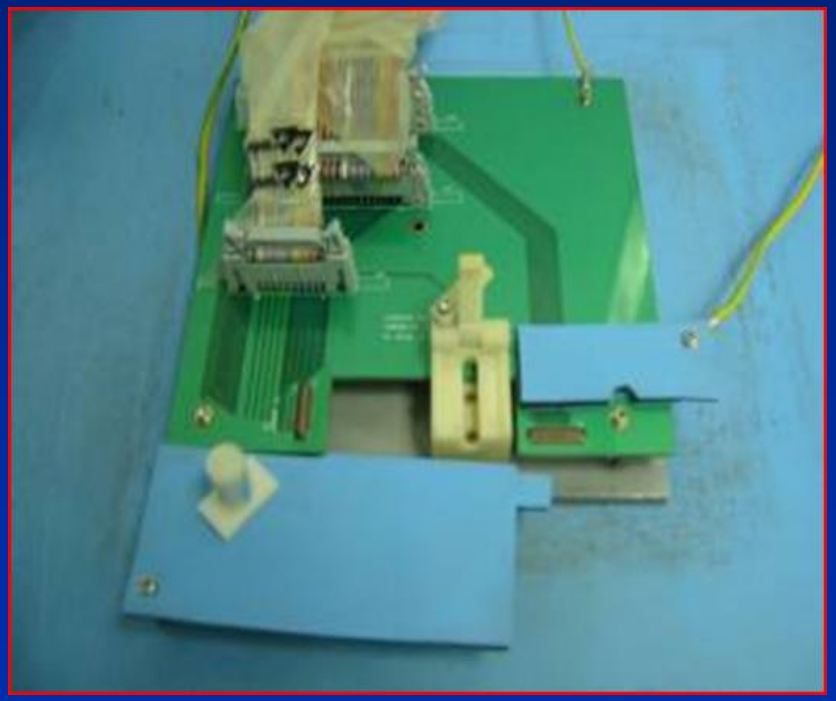
Horizontal: 1us/div

Vertical: 5mV/div

Trigger: 5mV

Class 0A – Customized Solution
Special Operating Procedure (SOP)

MR Head Test Fixture



SOP

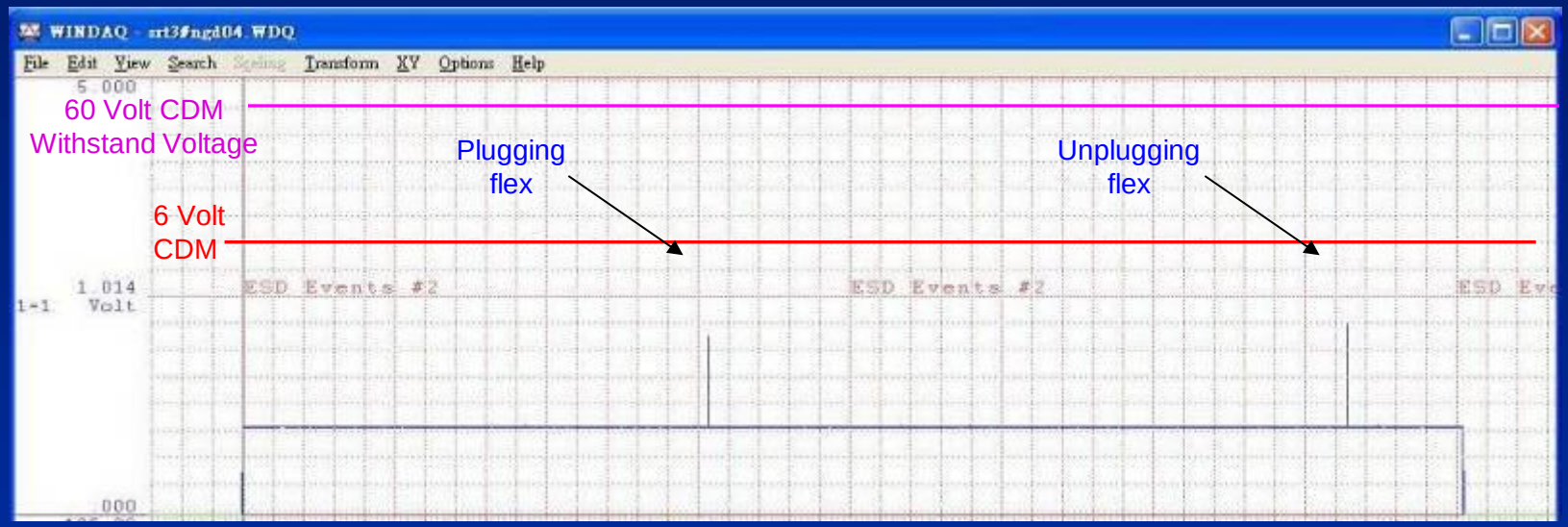
- **Dissipative Touch Pad For Flex Connector**
- **At Same Elevation As Test Socket**
- **Ground Flex Connector To Touch Pad For 4 Sec. Prior To Test**

SRT Current Probe Test Result Before/After New SOP*

Equipment	Transient Current (mA) at connector pin	
	Before	After
SRT #3	60-200	2.0-2.5
SRT #4	50-180	2.0-2.3
SRT #5	50-180	1.0-1.5

*Special Operating Procedure

MR Head Process Improvement Correlated ESD/EMI Test Result

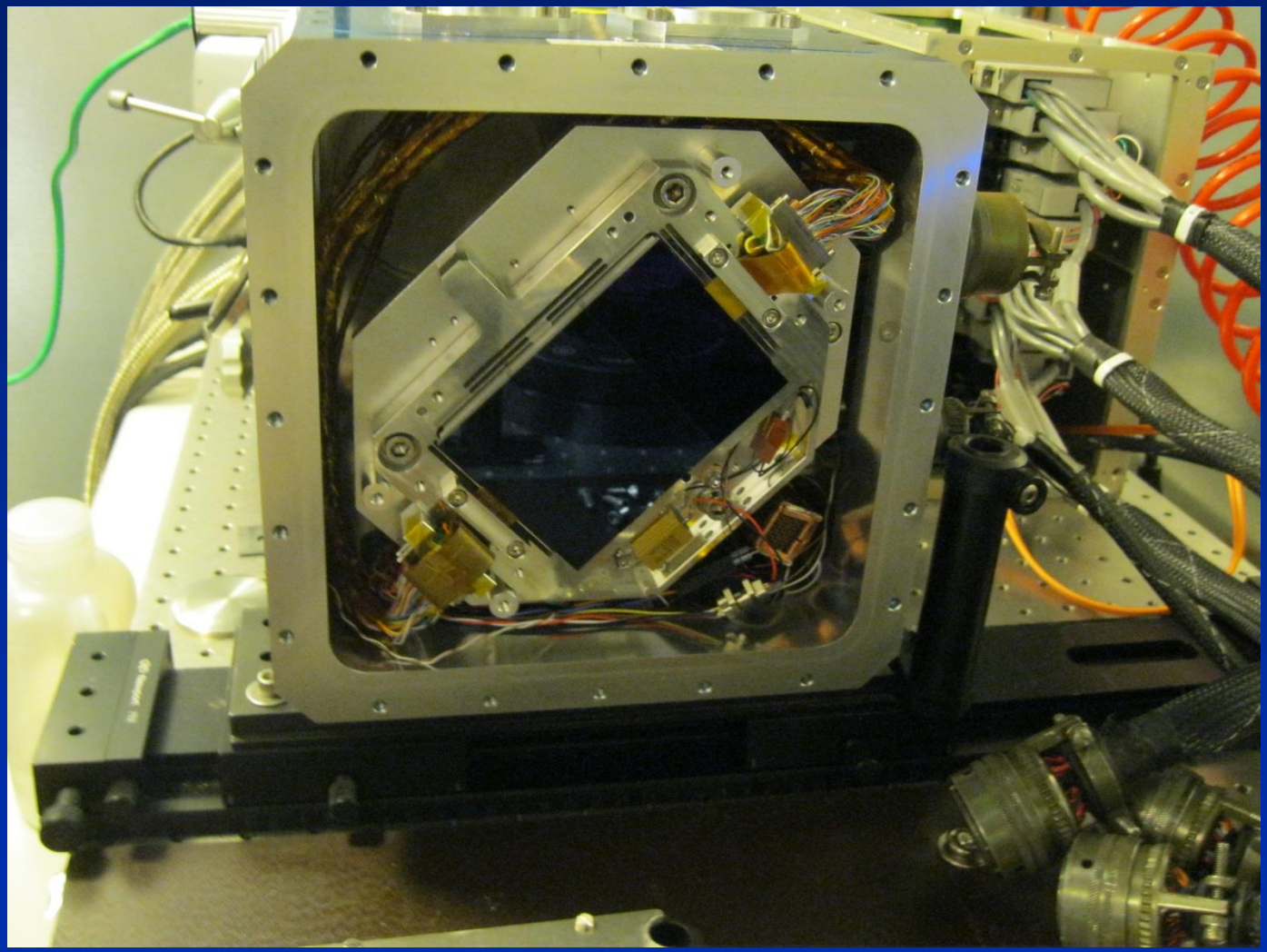


Class 0A ESD Engineering Requirements (1/10th of Thresholds) Satisfied With Margin to Spare

Gemini Telescope Class 0 Case Study
Background

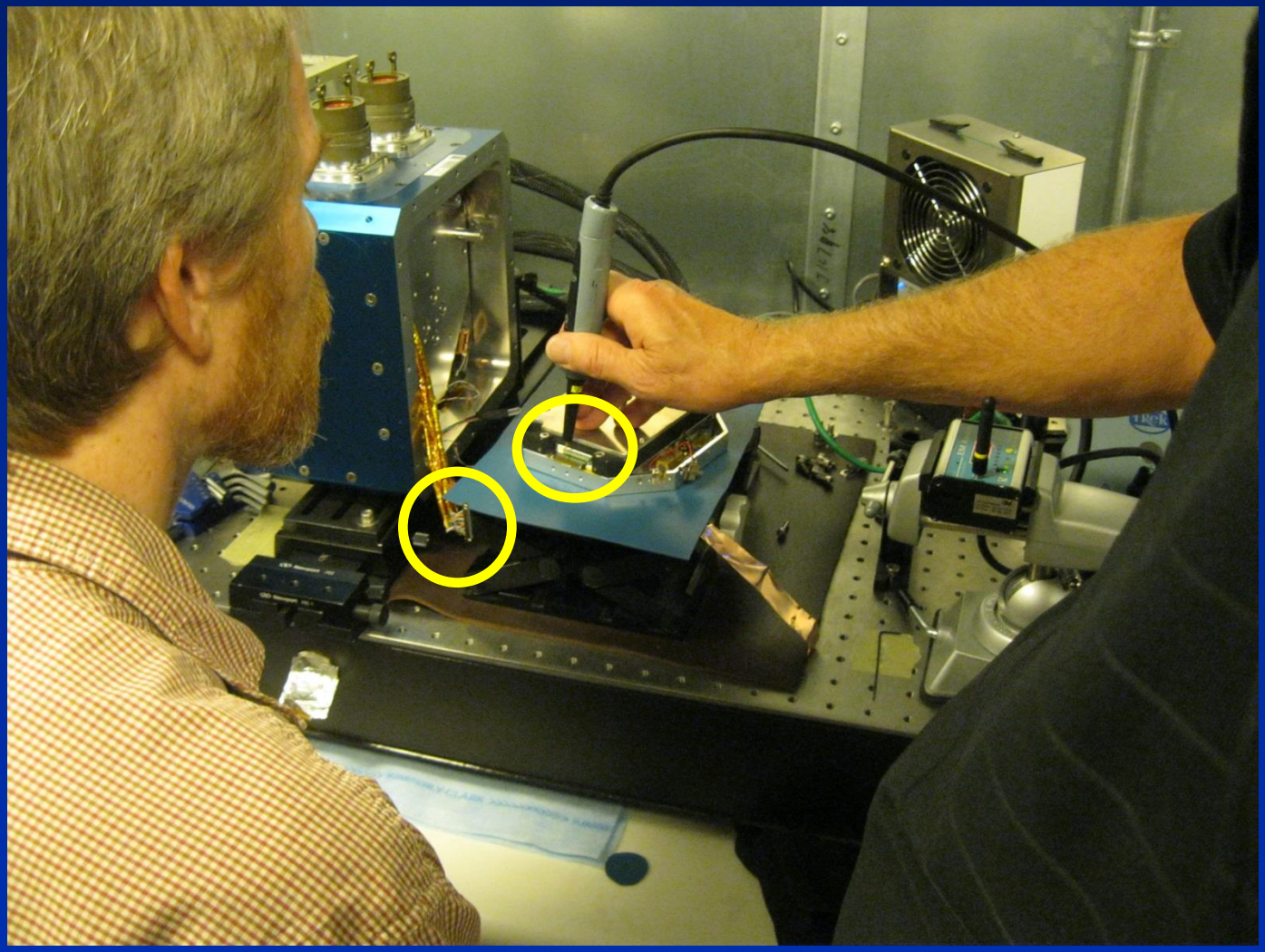
- **Objective: Replace 3 CCD Arrays**
  - **$175,000 Each Array**
  - **First Two Damaged with ESD**
  - **Obtained Expert Advice and Guidance**
    - **To Prevent Further ESD Damage**

Gemini Dewer



Contact Voltmeter Measurements

Objective: Every Pin Prior to Contact - Less that One Volt

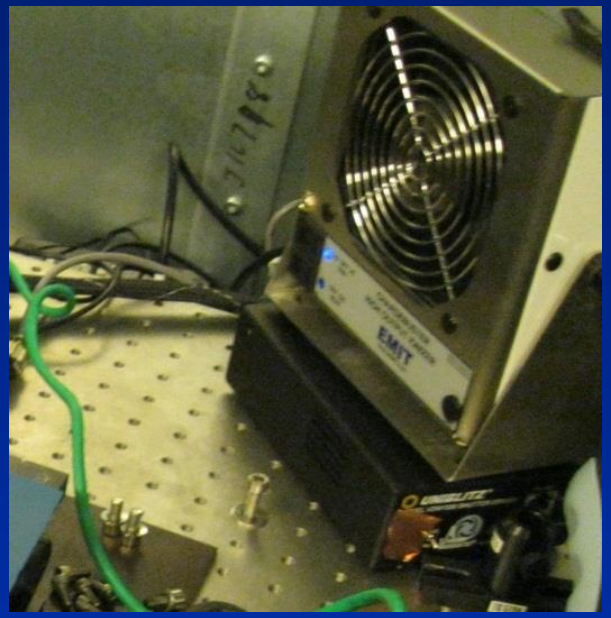


Class 000: Ionization Gun Essential Tool

DC Ionizing Gun

Essential for Lowering Pin Voltages below 1 Volt

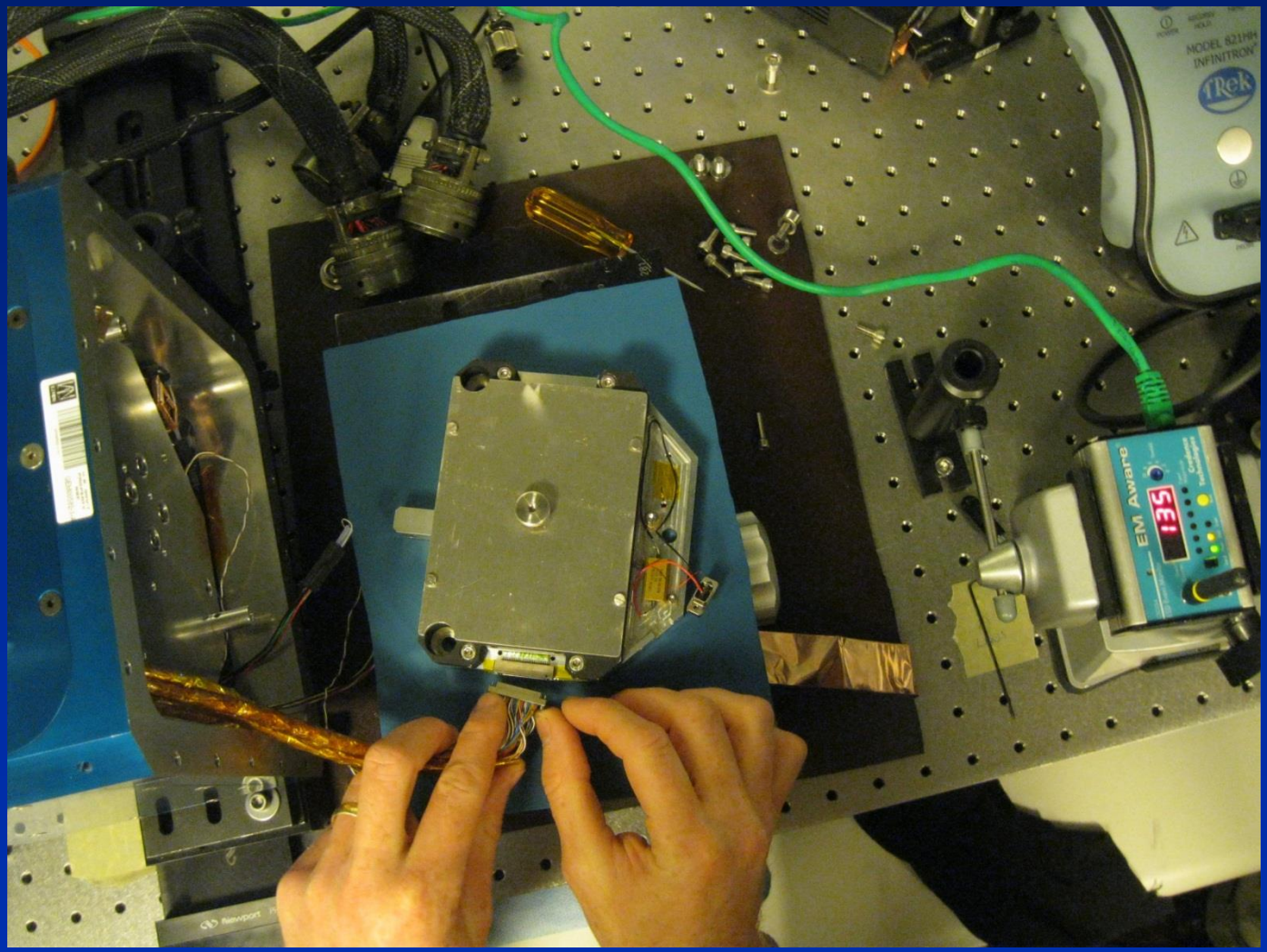
DC Bench Ionizer



1 Second Decay Rates Insufficient for Pin Voltage Reduction

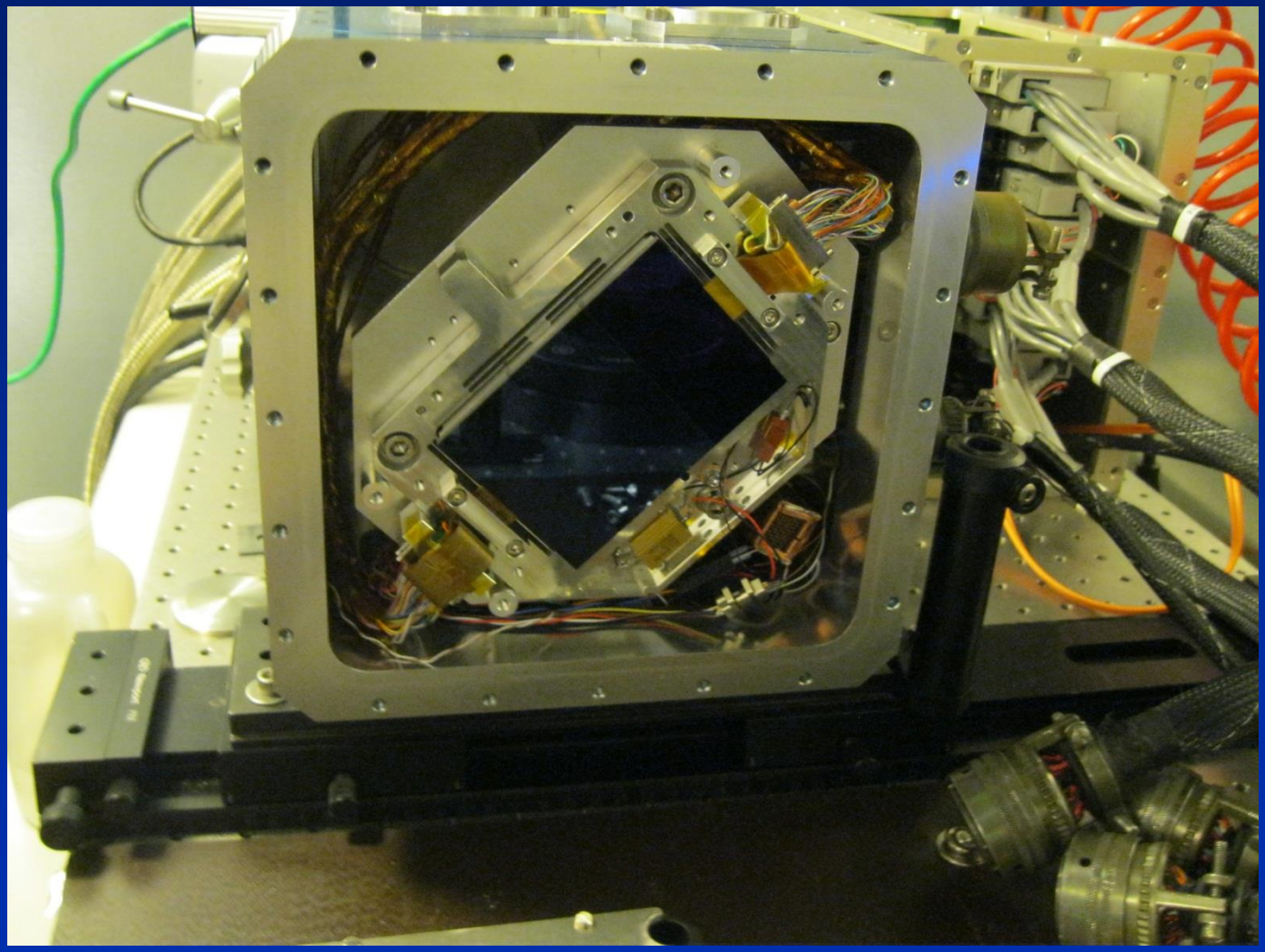
Event Free Insertion

Every Pin Prior to Contact - Less that One Volt



Successfully Installed CCDs

ESD Event Free – No ESD Damage!



Questions

Contact information:

Ted Dangelmayer

Terry Welsher

978 282 8888

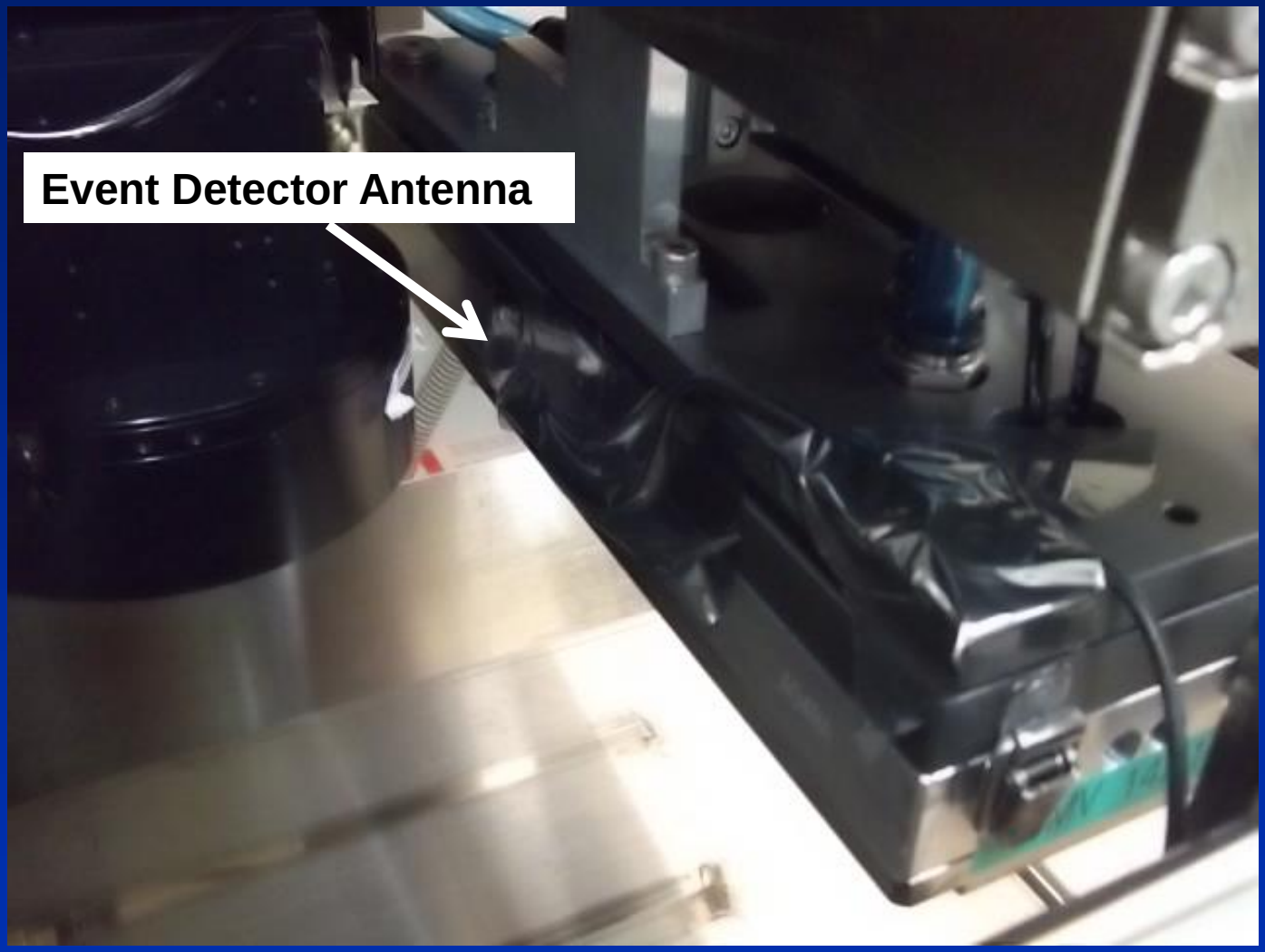
ted@dangelmayer.com

Automation Case Studies

Far More Complex!

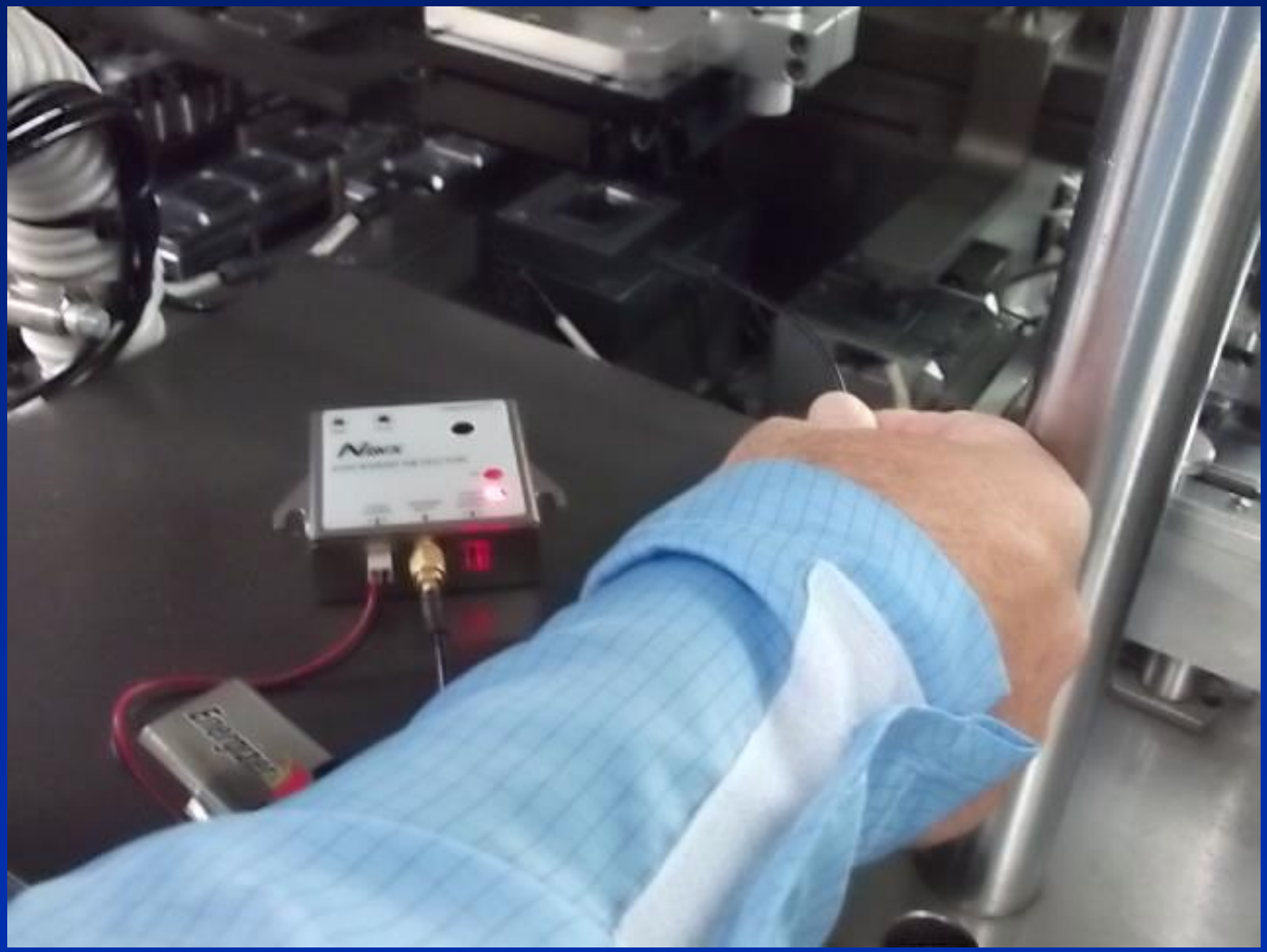
200 Volts on Device
Evaluate Risk With Event Detection

200 Volts:
No ESD Events Above 10 Volts



30 Volts on Device
Evaluate Risk With Event Detection

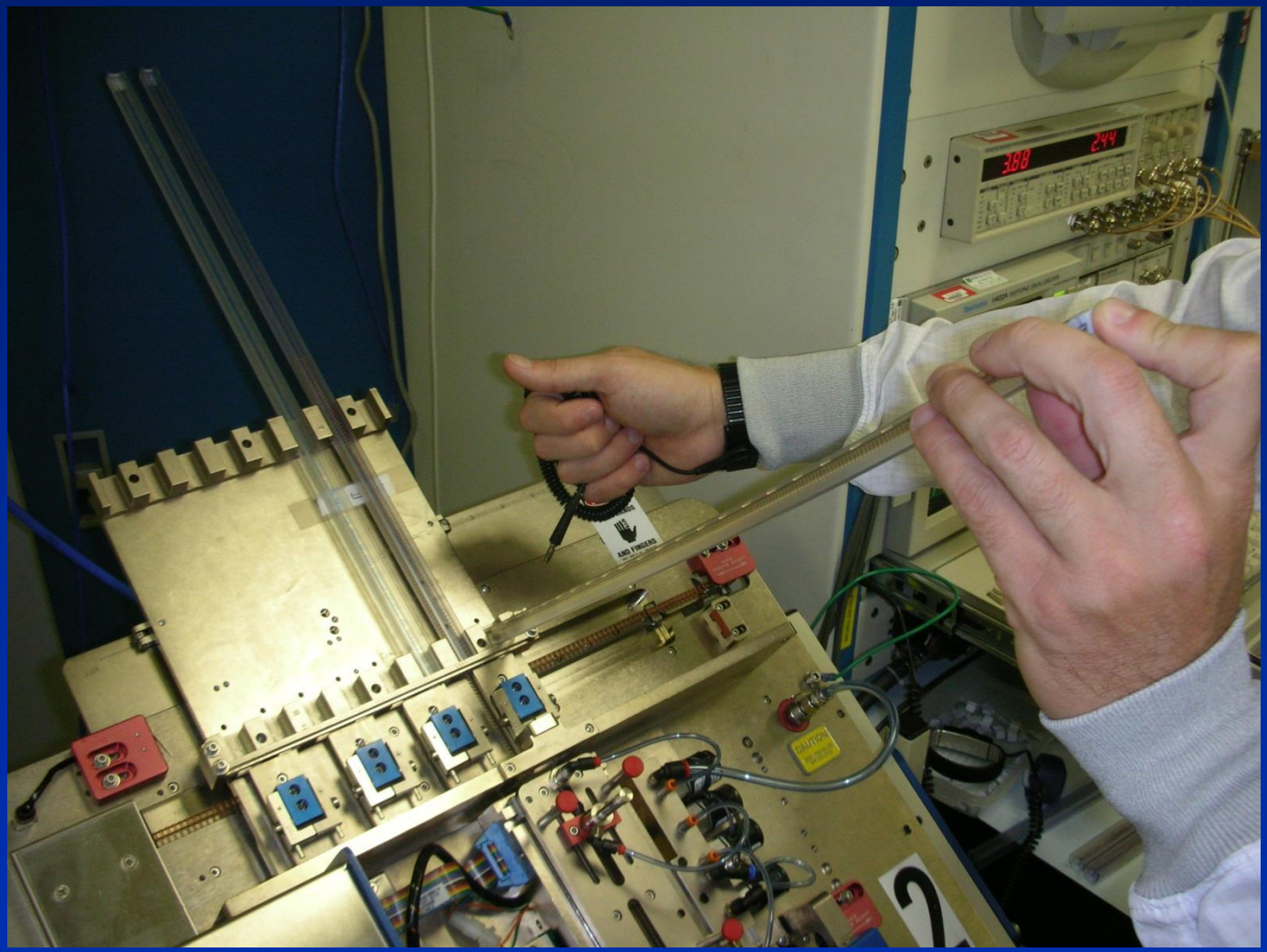
30 Volts on Device
ESD Events Detected – Must Determine Source!



Automation Video Class Exercise

Test Handler – Multiple ESD Events

Including Double Jeopardy & Class 0A Devices

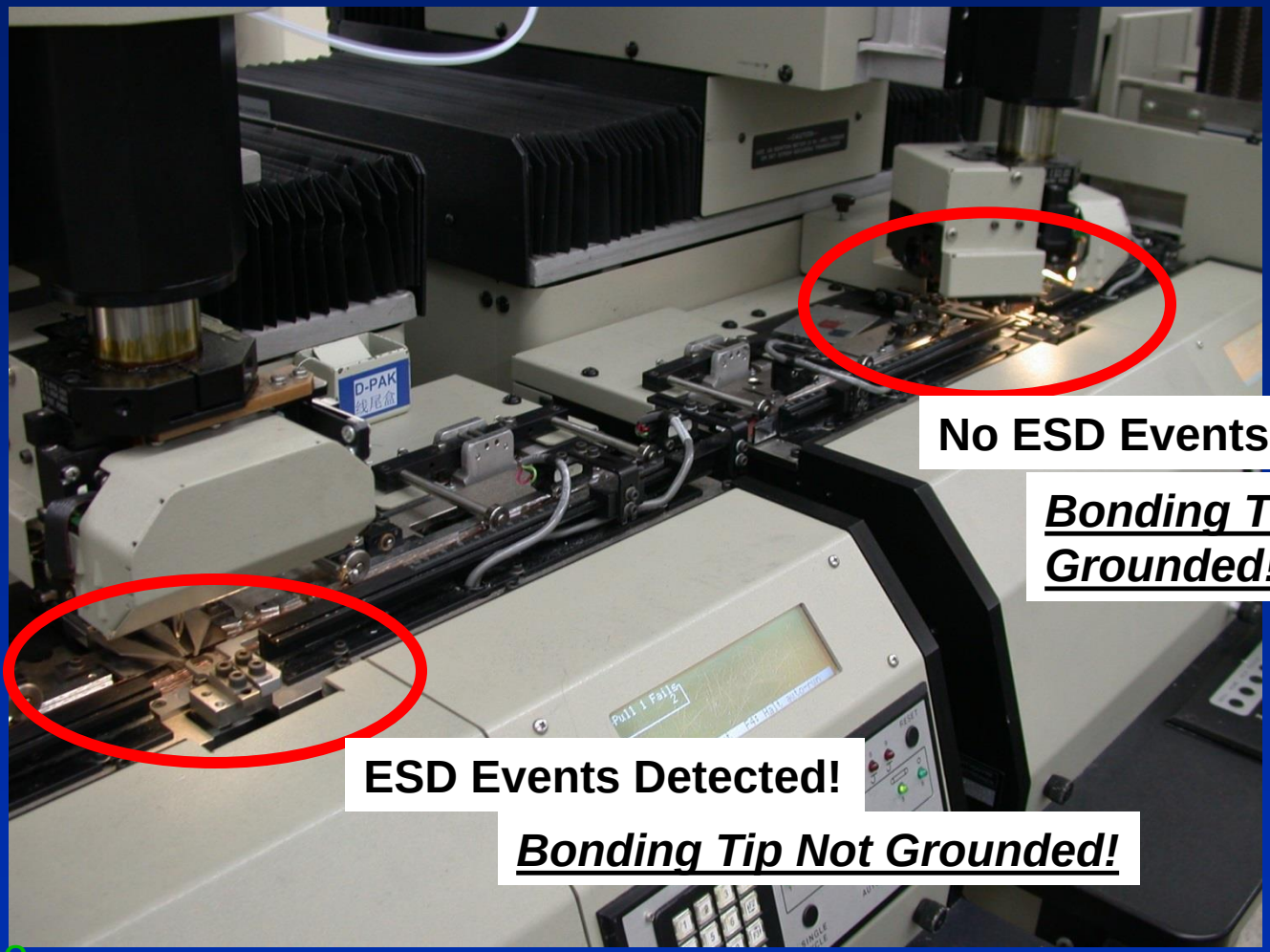


SMT ESD Events Common Issue

Must Locate & Eliminate Risk for Class 0

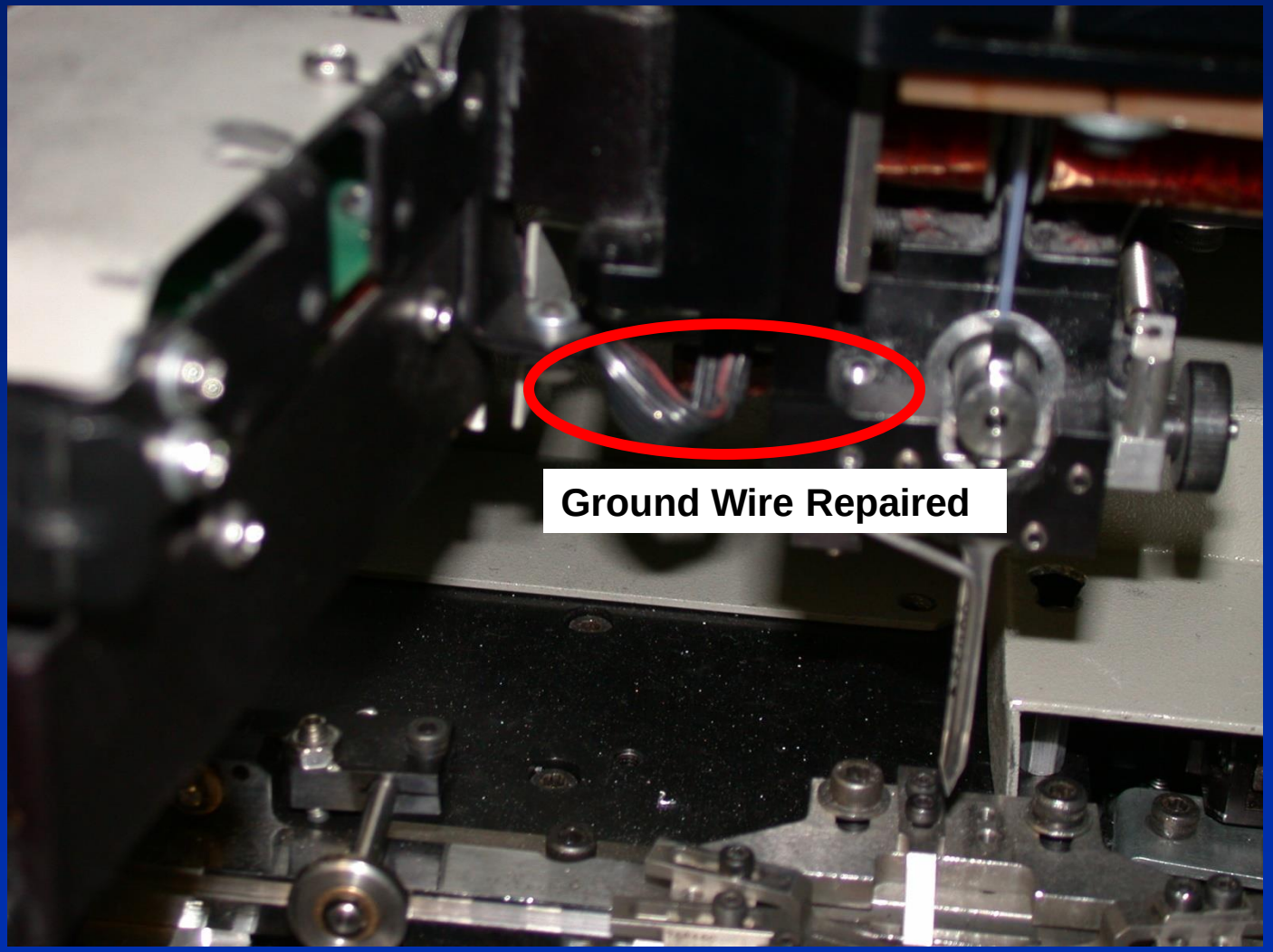
ESD Events in Glove Box Common Issue High Risk For Class 0A

Proper Grounding Essential
ESD Event Detection Good Analytical Tool



Event Video

Event Corrective Action — Repaired Grounding



An Example: HBM Latency Risk for MOSFETS:

Generic MOSFETs do display latent effects of sub-threshold events.

- Literature studies show significant damage only when pulses are within about 5-10% of the threshold (See Tunnicliffe et al J. Electrostatics 1993)
- Even then multiple pulses are typically required to produce the latent damage sites
- Normal HBM ESD precautions typically keep voltages well under 5 volts
- Excursions from normal are *highly unlikely* to produce damage in the latency region without also causing catastrophic damage to some parts.
- Thus, latency risk should track HBM ESD dropout risk
  - If no HBM ESD failures have been observed it is highly likely that no latent damage has occurred as well
  - If HBM failures have been observed, the risk of latency is the about the same regardless of which handling method is used.

Steps Taken To Resolve Yield Losses

Cost of Implementation = $335,000

(That Did Not Work!)

- Enhance ESD Training
- ESD Flooring & Footwear
- ESD Chairs, Garments, Carts
- Room Ionization & Bench Top Ionizers
- Constant Wrist Strap Monitors
- Daily SPC to Ensure Compliance to Procedure
- Dissipative Handling Materials & Containers

Event Detectors Useful for Workstation Analysis

Video

Photo Courtesy Dangelmayer Associates

Grounded Springs Added to Conveyor
to Ground ESD Product Trays

ESD Events Due to High Charging Carts