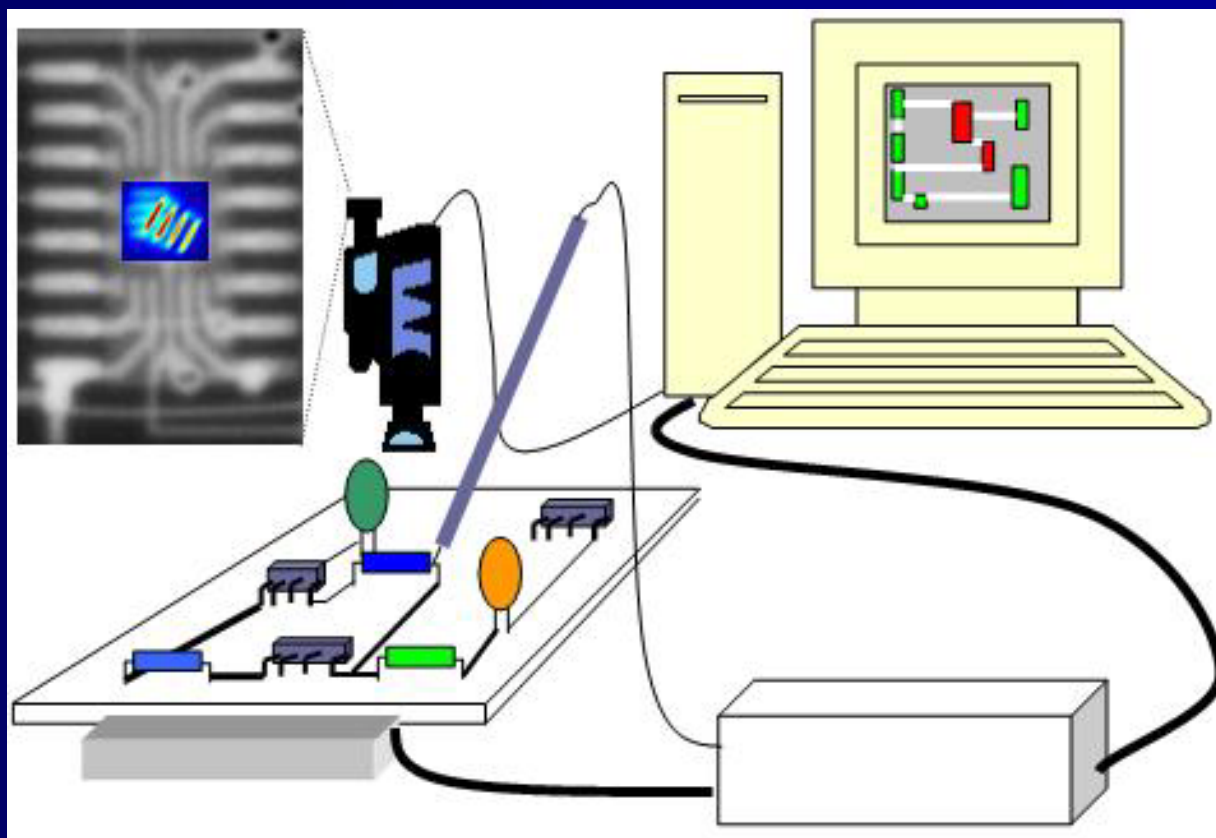




**RMD**

# Damage Characterization Assessment of Circuit Cards Through Nanotechnology





## Problem with Existing Printed Circuit Board (PCB) Inspection Technology

- › Cannot pinpoint the faulty component
  - Provides a list of suspect PCB components to replace
- › Cannot diagnose intermittent failures
- › Cannot estimate remaining lifetime of components
- › Cannot identify or locate incipient microstructural damage that can lead to premature failure



**RMD**

# Platforms That Can Benefit

- › Initial Target
  - LAV 25 (Light Armored Vehicle)
  
- › Other Ground Vehicles
  - AAV (Amphibious Assault Vehicle)
  - EFV (Expeditionary Fighting Vehicle)
  
- › Ordnance
  - TOW Missile System
  - LW155 ( Lightweight 155 Howitzer)
  
- › Radar & Communication
  - GATOR (Ground/Air Task Oriented Radar)
  - AN/TRC-170





# Baseline PCB Inspection Technology

**RMD**

- › Dynamic testers (TETS)
  - Expensive
  - Requires custom interface
  - Produces “ambiguity list” of suspect components



- › Curve tracers (Huntron)
  - Need to scrape through conformal coatings
  - Requires expert to analyze result
  - Cannot perform functional test after repair

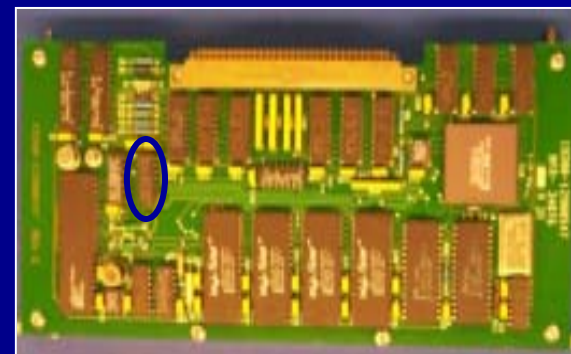


- › Neither technology can locate microscopic flaws that lead to intermittent PCB failures



## Customer Needs

- › Pinpoint failed components
- › Detectability of incipient defects
- › Diagnose intermittent failures
- › Prognostic estimate of remaining lifetime



- › Portable
- › Rugged



- › Minimal operator training
- › Rapid, high-throughput inspection
- › Low cost

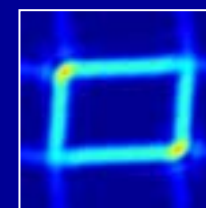
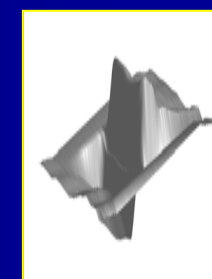
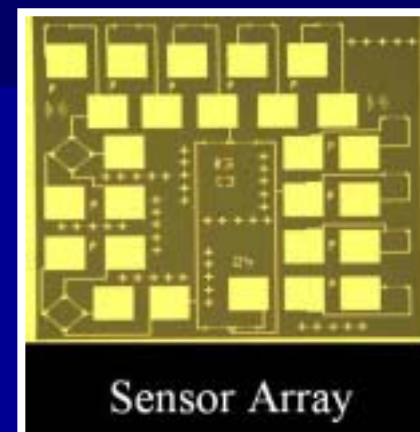




# RMD

## RMD's Solution

- › Leverage Core Technologies:
  - Solid-state sensing elements
    - › Robust; microscopically small (< 2 microns)
    - › Magnetic sensitivity unmatched at small size
      - Competitive with SQUID at <10 microns
  - Signal processing electronics
    - › Custom hardware
    - › Algorithms for noise reduction
  - Proprietary imaging methods
    - › 3D geometry of microscopic flaws
    - › High-resolution magnetic imaging

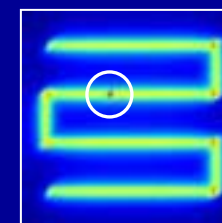




# RMD

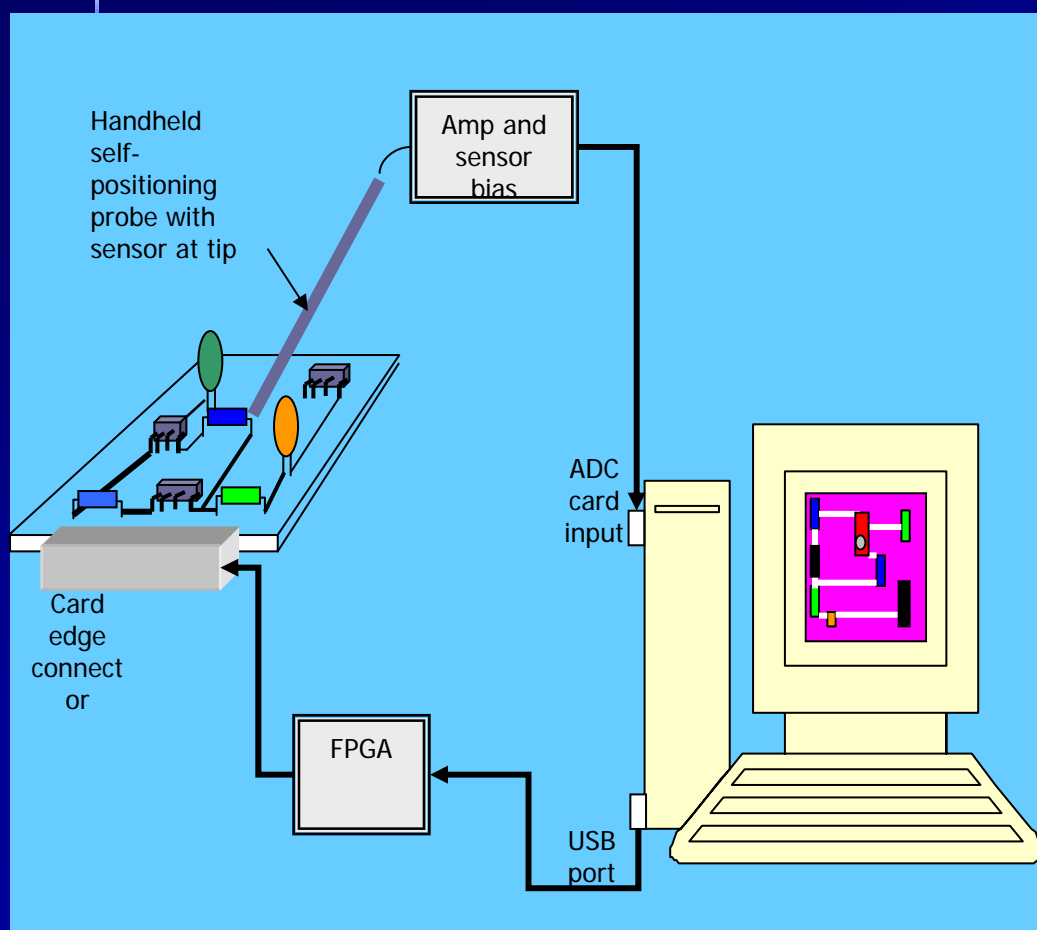
## RMD's Solution

- › PCB Inspection System
  - Portable PC-based
  - Low cost
  - Versatile
  - Unprecedented capabilities
  
- › Uses innovative RMD technologies
  - Microscopic solid-state sensors
    - › Increased sensitivity compared to coil magnetometers
  
  - Nodal analysis
    - › Proprietary signal processing algorithms
    - › Pinpoints failed and/or failing components
  
  - Magnetic imaging
    - › High spatial resolution to locate microstructural defects





## Nodal Analysis – Finding failed components



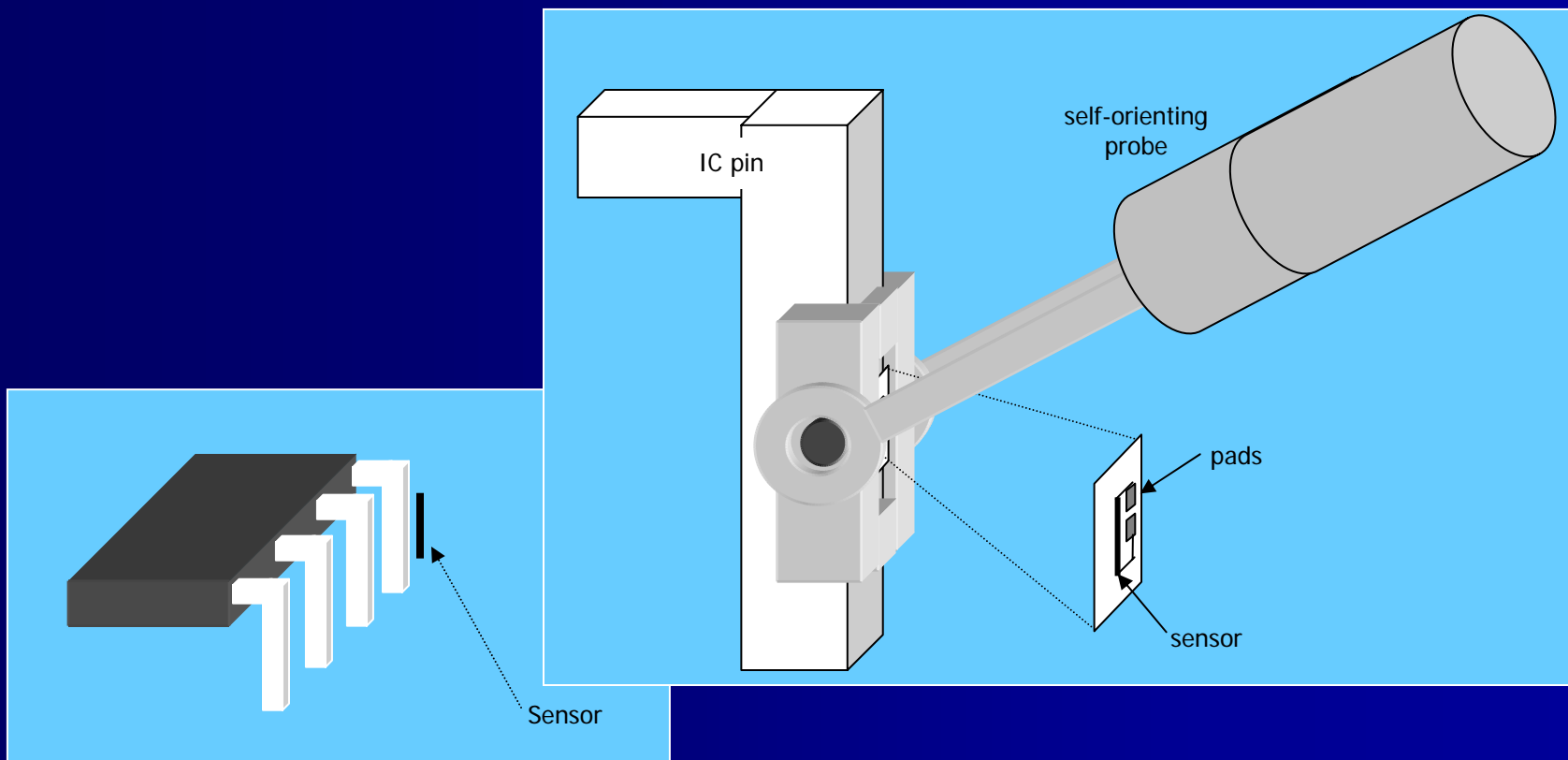
Measures electrical parameters on PCB pin  
– Noncontact; measures through conformal coating





# Nodal Analysis – Finding failed components

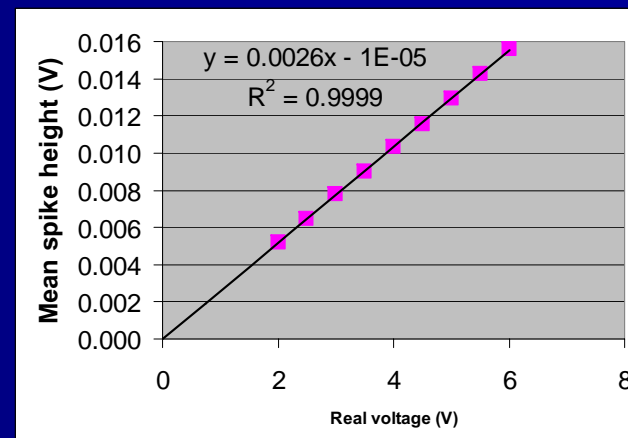
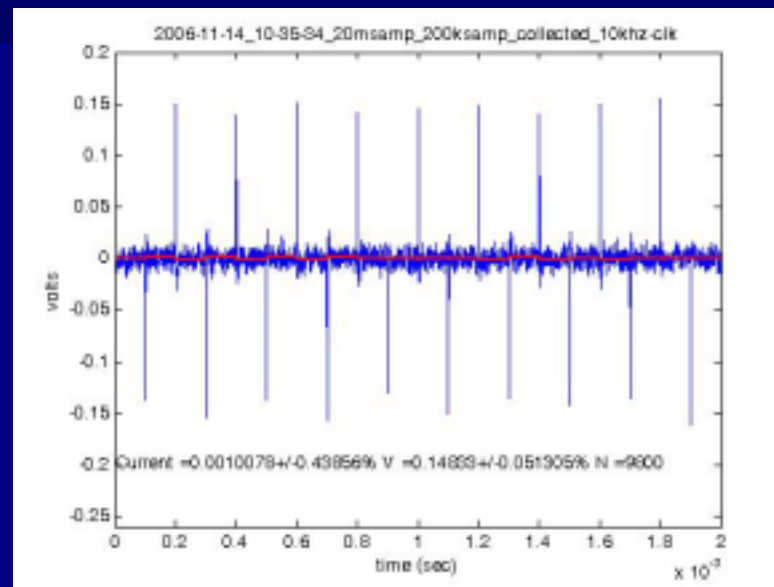
- › Manual sensor probe





## Nodal Analysis – Finding failed components

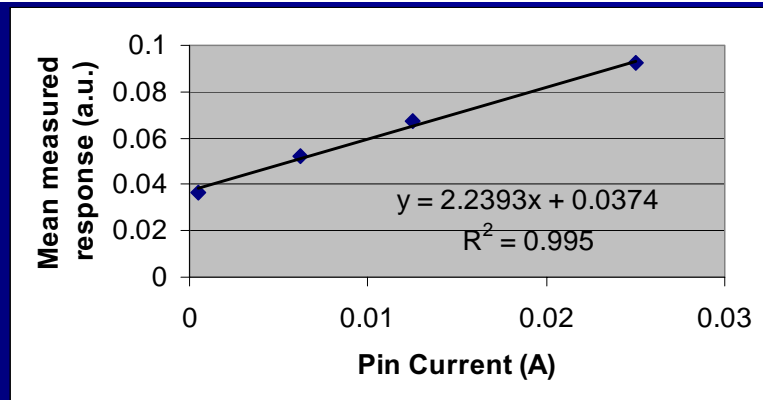
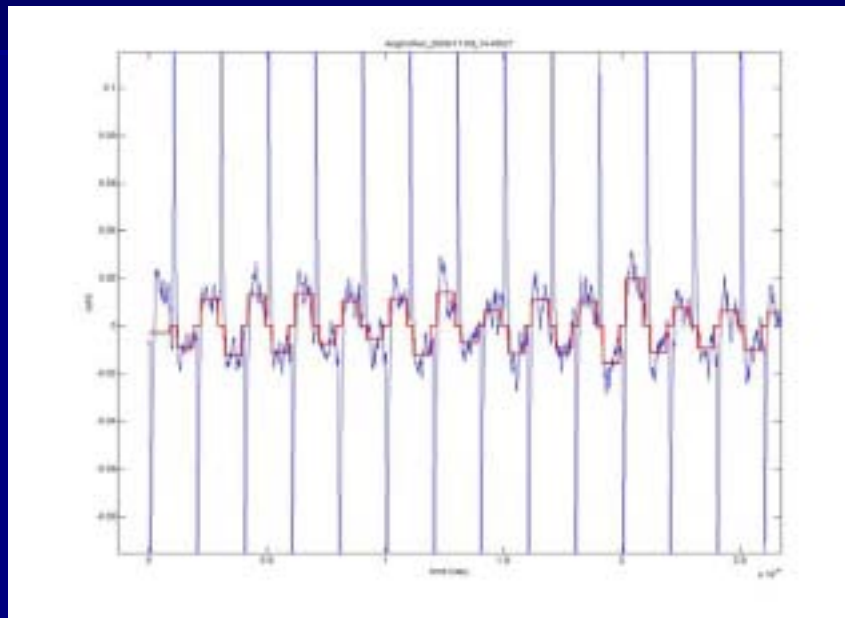
- › Non-contact Digital Signals
  - **Voltage**
    - › Spikes occur at digital transitions
    - › Signal amplitude proportional to CMOS integrated circuit chip (IC) pin voltage
    - › Provides frequency, digital waveform





## Nodal Analysis – Finding failed components

- › Digital signals
  - **Current**
    - › Signal between spikes is proportional to pin current
- › Analog Signals
  - Phase of sensor signal is used to distinguish between voltage and current

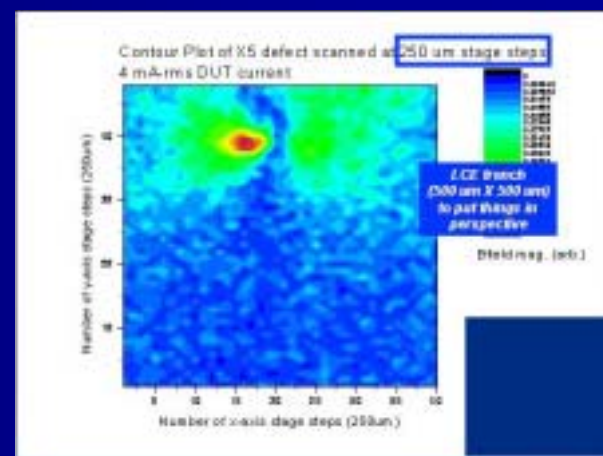
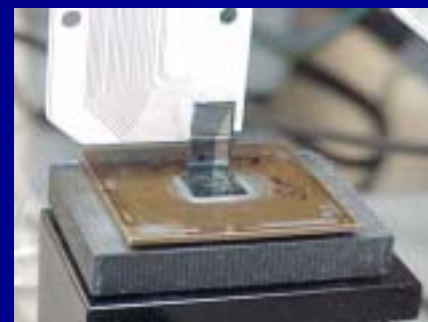




## Magnetic Imaging - Aging and microstructural defect analysis

- › **Magnetic field image of IC**
  - Creates magnetic field map or image (MFI)
  - Compare to gold standard to find failed/failing parts and localize microstructural defects
- › **Active mode**
  - MFI of PCB components under operation
- › **Passive mode**
  - MFI from eddy currents induced in PCB, IC traces
- › **Problem: Field diffuses rapidly with distance**
  - Solution: Use MFI with RMD algorithms to recover image of defect

Inspecting an Intel P-4 CPU to produce magnetic image





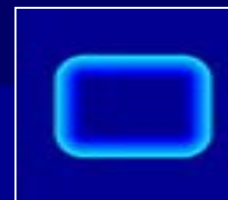
## Magnetic Imaging -

### Aging and microstructural defect analysis

- > Standard magnetic image degrades rapidly with increasing sensor distance and increasing sensor noise

- > RMD algorithm
  - Filters frequency components
  - Recovers magnetic field image at distance

Simulated current in IC



Increasing distance à

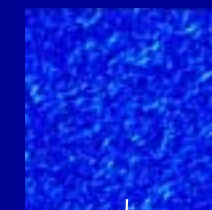
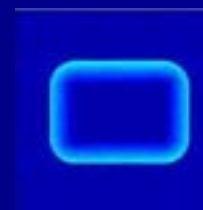
0.1 micron



10 micron

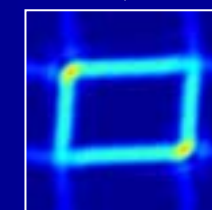


Images with existing technology



Increasing noise à

Recovered image using RMD filtering



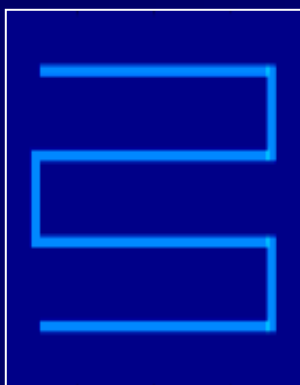
z = 10 micron  
SNR = 1000



## Magnetic Imaging - Aging and microstructural defect analysis

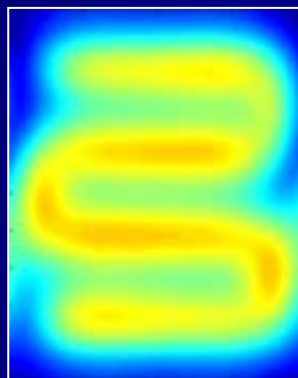
- › IC inspection for aging and incipient defects
  - Uses optimized filter to recapture electric current profile in an IC

Original current  
in structure on  
IC



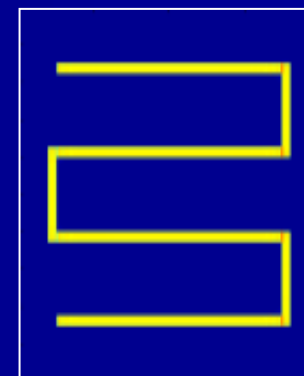
FOV = 70 x  
100 micron

Magnetic  
field image



Sensor distance =  
2 micron

Recovered  
image using  
RMD optimized  
filter



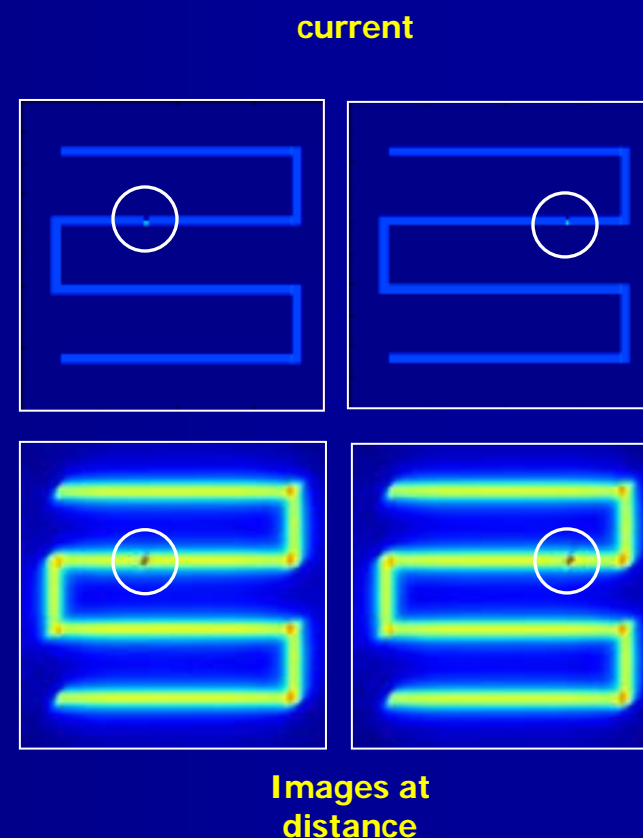


## Magnetic Imaging -

### Aging and microstructural defect analysis

- > Detection and mapping of a sub-micron sized mouse-bite inside an integrated circuit (IC) chip
- > Microscopic resolution is achievable from outside the IC package

Minimum detectable defect	Distance, sensor to IC = z
0.134microns	4 microns
3.35 microns	100 microns
33.5 microns	1000 microns=1mm





## Magnetic Imaging -

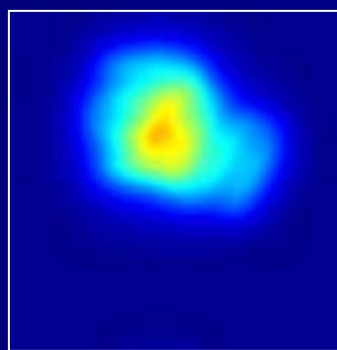
### Aging and microstructural defect analysis

- › Detection and imaging of traces inside an IC from a sensor distance of 1 mm
  - Simulation of field scanning from outside the IC package
  - Resolution  $\approx$  15 microns

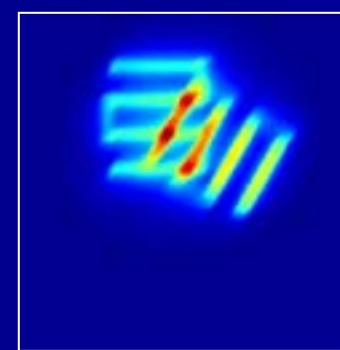
Original current



Magnetic field image



Recovered image





## Magnetic Imaging -

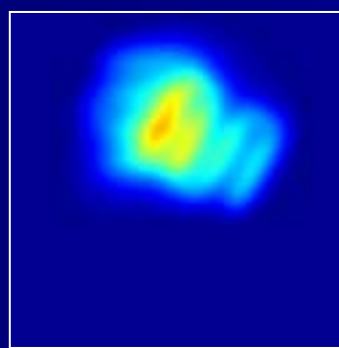
### Aging and microstructural defect analysis

- › Detection and imaging of traces on different layers within an IC or PCB
  - One layer at sensor distance of  $z = 1$  mm
  - Other layer (structure at  $45^\circ$ ) at  $z = 0.75$  mm
  - Both structures are recovered

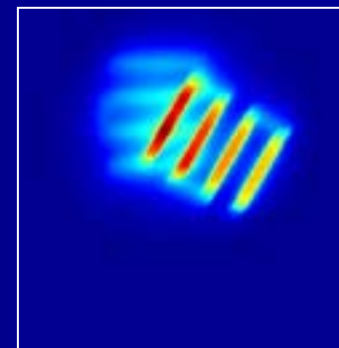
**Original  
current map**



**Magnetic  
field image**



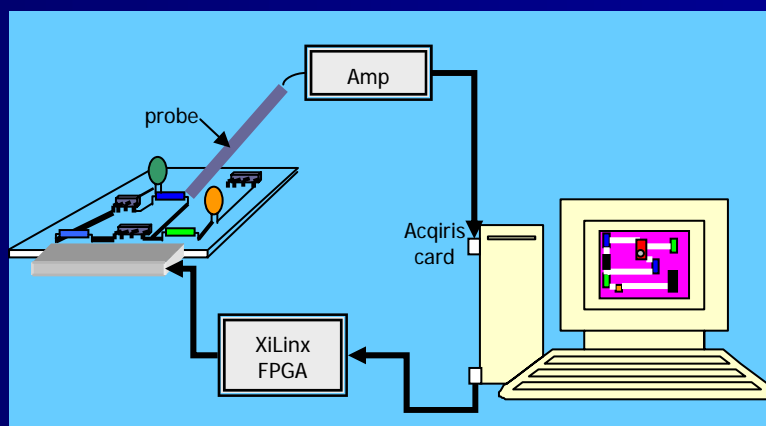
**Recovered  
current map**





## Prototype PCB Inspection System

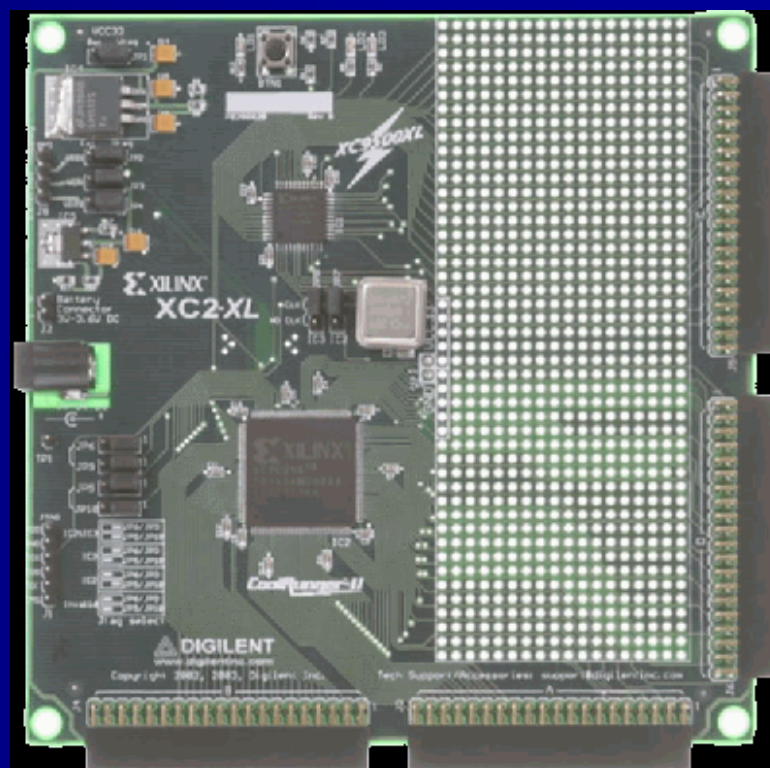
- › System Components
  - Hardware
    - › Windows computer
    - › Field-Programmable Gate Array (FPGA) for PCB stimulation
    - › Manual probe and amplifier
    - › Data acquisition card





## Prototype PCB Inspection System

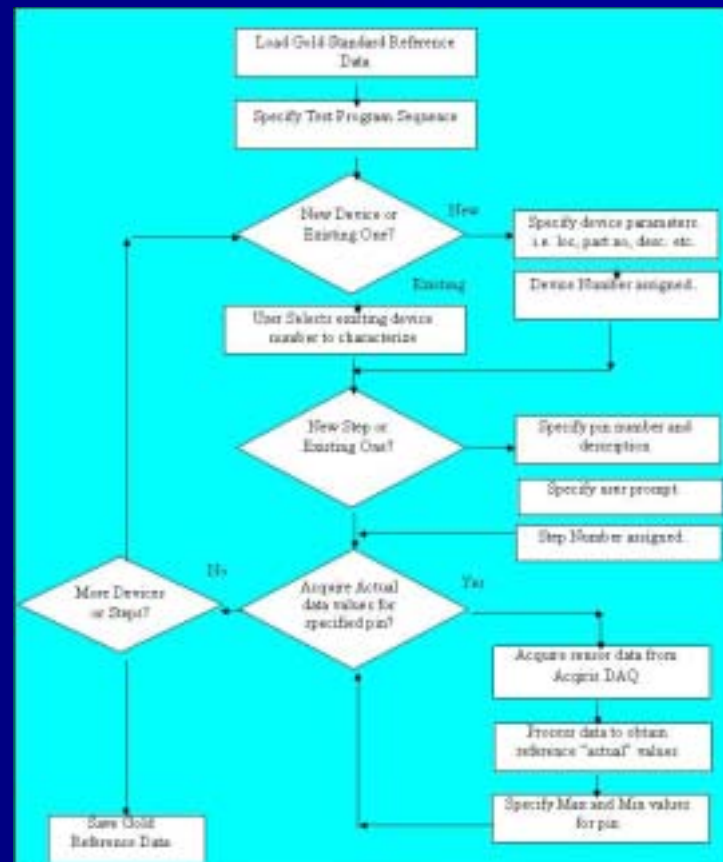
- › PCB/Computer Interface
  - Programmable FPGA
    - › Minimal customization of hardware interface
    - › Specify connector for individual PCB
    - › Stimulates every component on the PCB





## Prototype PCB Inspection System

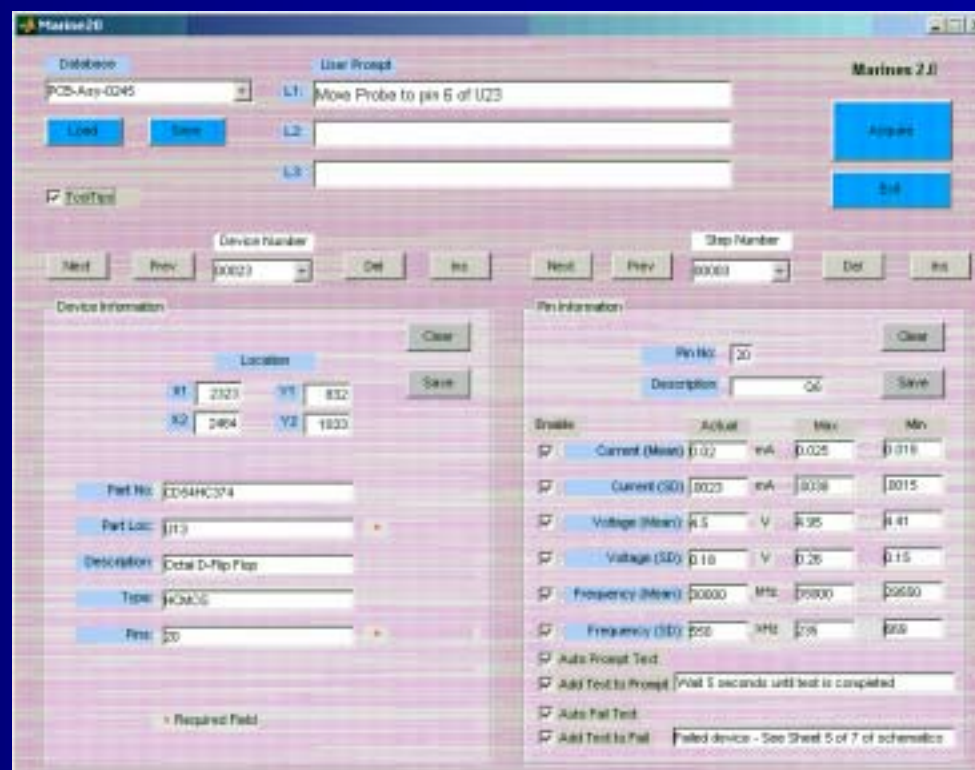
- › Software
  - Single application controls:
    - › Graphical User Interface (GUI)
    - › FPGA, PCB stimulation
    - › Data acquisition control
    - › Analysis algorithms
  - Operator friendly





## Prototype PCB Inspection System

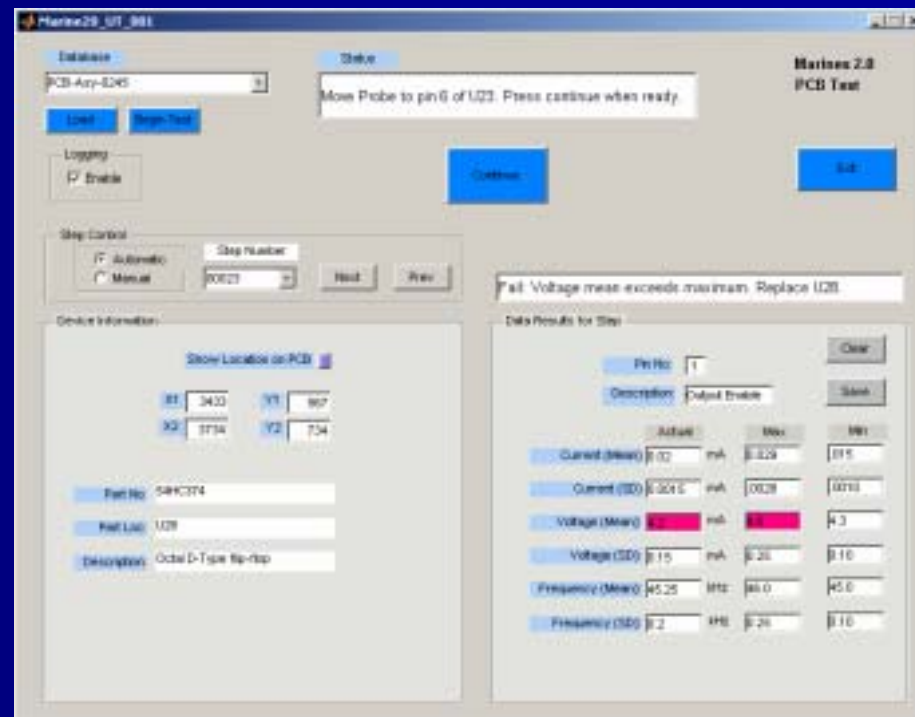
- › Gold standard
  - Engineer creates test sequence
  - Operator conducts test on functioning PCB
  - Creates stored “gold standard” data





## Prototype PCB Inspection System

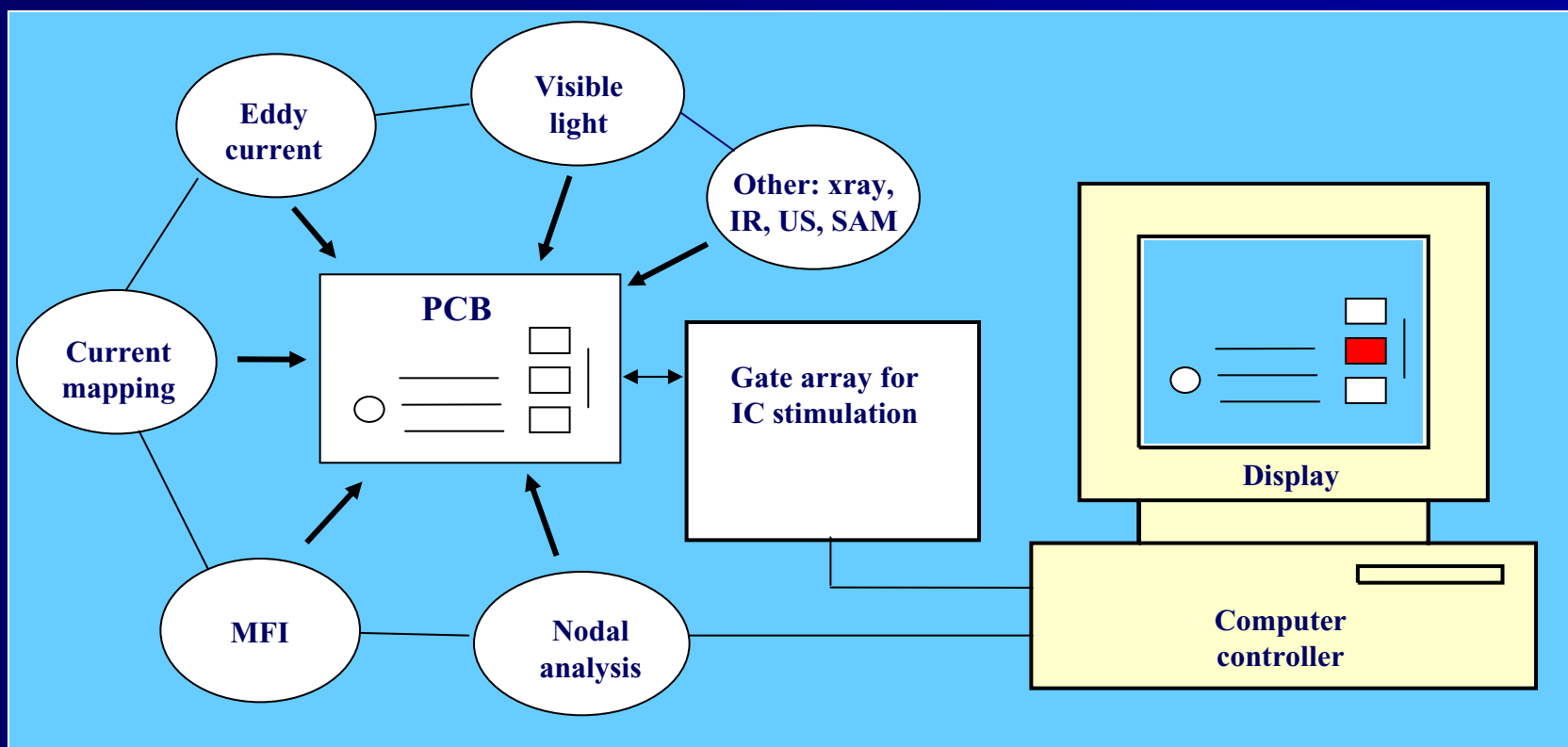
- > Automation
  - GUI visually guides operator through test sequence
- > Bad Component Detection
  - Statistical comparison with gold standard data
- > Functional test
  - Shows that PCB is working after component replacement






## PCB Inspection System

- › RMD technology has a variety of imaging and analysis modalities that can be correlated to expand its abilities



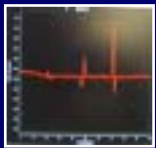
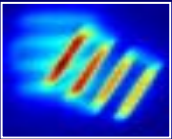


# Benefits of RMD's PCB Inspection Technology

<i>Feature</i>	<i>Advantage</i>	<i>Benefit to Customer</i>	
Microscopic, solid state sensors and sensor arrays  Microscopic Sensor	High signal-to-noise ratio	Rapid detection of failed components	
	Low-cost	Cost-effective solution for platform's inspection needs	
	High spatial resolution		Detect small, incipient defects
			Accurate microstructural flaw localization
	Robust	High repeatability	



# Benefits of RMD's PCB Inspection Technology

<i>Feature</i>	<i>Advantage</i>	<i>Benefit to Customer</i>
Advanced signal processing and electronics 	Precise I, V, frequency, waveform measurement	Enables rapid, automated analysis and detection of failed and failing components
	Low noise	Enhances detectability of faults
Passive mode	Inspect dead PCBs	No need to provide power
Active mode	Performs functional test	Additional dynamic test is unnecessary
Imaging capability 	Can see inside ICs and multilayer PCBs	Detect and localize hidden faults leading to intermittent failure and reduced lifetime of components

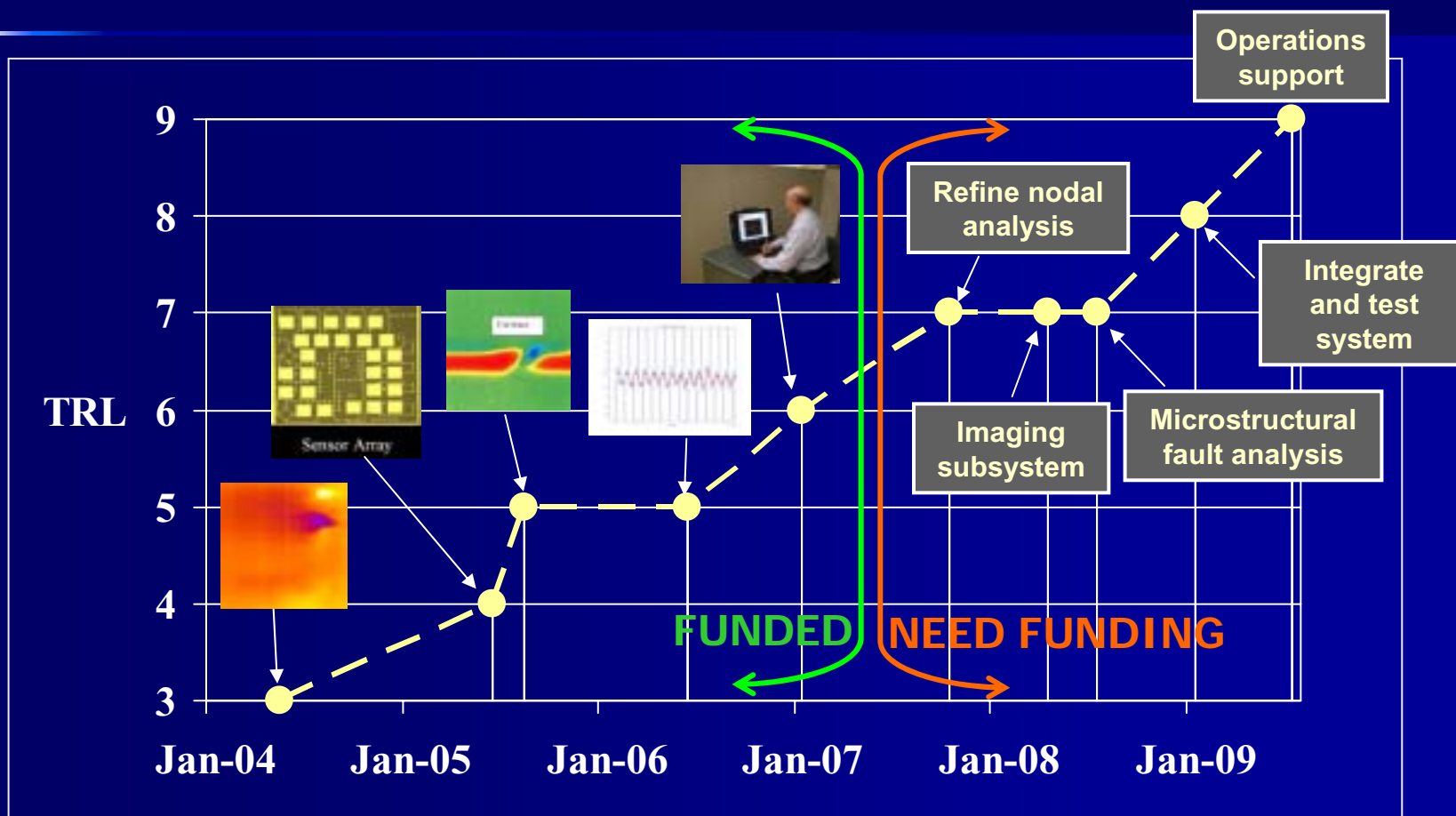


# Comparison of PCB Inspection Technologies

	RMD	TETS	Huntron
Finds failed component	*****	***	***
Ease of use	*****	*****	***
Performs functional test	*****	*****	*
Measures through conformal coatings	*****	***	**
Detects aging effects	****	*	*
Detects effects of damage	****	*	*
Detects "cannot duplicate" faults	****	*	*
Detects incipient defects	****	*	*
Images hidden microstructural flaws	*****	*	*
Cost	\$15-60k	\$250k	\$15k-50k



## Transition to the Fleet





**RMD**

## Partners Sought

- › RMD seeks to supply and develop its innovative NDI technology for :
  - Defense Program Managers
    - › Marines electronics maintenance (TMDE)
    - › Other DoD electronics maintenance facilities
  - DoD Prime Contractors, System Integrators
  - Commercial industrial partners



**RMD**

## RMD Related Products

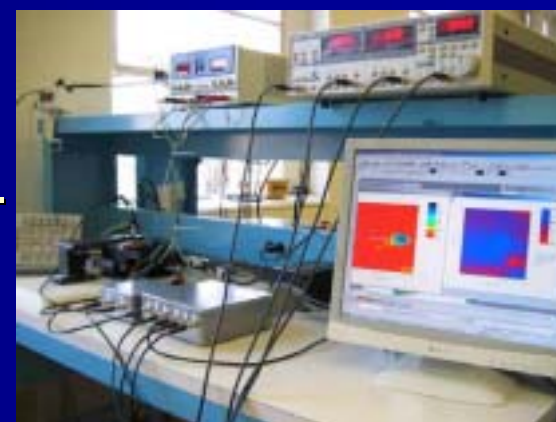
- › Inspector® lead paint analyzer



- › Navigator™ intra-operative surgical probe



- › PCB inspection system for INTEL, Inc.





# RMD Contact Information

- › Timothy C. Tiernan
  - Director, Advanced Instrumentation Division
    - › 617-668-6856
    - › [ttiernan@rmdinc.com](mailto:ttiernan@rmdinc.com)
  
- › Mark Steinback
  - Senior Scientist
    - › 617-668-6860
    - › [cford@rmdinc.com](mailto:cford@rmdinc.com)