ePrognostic Systems LLC

Larry Thomas, Jr.
President

Copyright © 2007 CALCE

ePrognostic Systems LLC

Yes! Autonomous Environments Monitoring, small enough to be a mailing label on a legal size envelope.

About the size and thickness of 3 stacked business cards or
86mm x 55mm x 1.5mm
(3.4"x 2.17"x 0.06")

Non-intrusive to even very small packages or tight space areas where environments condition tracking is important… Just imagine the convenience for your expensive equipment in shipment or in use. Adhesive backed for ease of mounting. Environmentally rugged itself (Specs below).

Available now for Temperature monitoring and reporting, with long battery life and reusable for multiple cycles of reuse. Programmable time intervals of data sampling, Temperature with date and time stamp for each recorded measurement Currently over 700 recoded data points held in internal memory, RFID readable and programmable (close proximity for security), Delayed start option for maximum utilization of memory, Multiple modes of measured data recording: Continuous recording at each measurement/sample time, Record only temperatures above a high threshold and below a low threshold (saving memory and allowing longer monitoring elapsed time), Record only when crossing High or Low thresholds (ultimate memory utilization (thresholds programmable at setup time),

Near term features will include security functions like passwords protection, as well as real-time tamper monitoring and reporting.

Need more - This tag has undergone prototype testing at Army-Aberdeen Proving Grounds. (Environmental monitoring performance results available at a later date.)

Still need more – the next generations will add Relative Humidity monitoring in much the same methodology as described above for temperature.

What's next –more data storage space is planned and vibration monitoring is on our roadmap (time frame not yet defined).
(Operating temperature and humidity to be added soon.

Copyright © 2007 CALCE

ePrognostic Systems

PHM-Tag

CALCE Copyright

Center for Advanced Life Cycle Engineering

Provide a knowledge and resource base to support the development and sustainment of competitive electronic products and systems in a timely manner.

Copyright © 2007 CALCE

CALCE Organization

- 17 research faculty
- 6 technical staff
- 60+ PhD candidates
- 30+ MS candidates
- 11 visiting scholars

Copyright © 2007 CALCE

CALCE Facilities and Capabilities

Environmental/Accelerated Testing
Temperature-Humidity Chambers
HALT Temperature-Vibration Chambers
Thermal Shock Chambers
- *Liquid to Liquid*
- *Air to Air*

HAST Temperature-Humidity Chambers
High Altitude Simulation Chamber
- *Pressure, Humidity, and Temp. Cycling*

High Temperature Aging Chambers
Mixed Flowing Gas (MFG) Chamber
Electrodynamic Vibration Chamber
Impact and Drop Test Apparatus

Sample Preparation
Diamond Saw
Polishing and Grinding Station
Plasma Etching
Ultrasonic Cleaning
Wire Bonder
Die Bonder

Thermal Assessment and Management
Liquid Crystal Thermography
Low Speed Wind Tunnel
Hot Wire Anemometer
Flow Visualization System
High Speed Video Camera
Thermal Conductivity Testing System
Laser Flash Thermal Property Measurement System
Flow/Velocity Measurement Facilities
Pressure Measurement Facilities

EMI/EMC Characterization
EMC Analyzer
Carrier Wave Generator
Semi-anechoic Chamber
Vector Network Analyzer
Susceptibility Testing
Precision Spherical Dipole
Low and High Impedance Probes for EMI/EMC Diagnostics
Shielding Effective Measurements

Non-Destructive Evaluation
3D X-ray Imaging System
Scanning Acoustic Microscope (SAM)
Fourier Transform Infrared Spectroscopy (FTIR)
Energy Dispersive Spectroscopy (EDS)
Atomic Force Microscope (AFM)
Automated Contact Resistance Probe (ACRP)
Infrared Microscopy
X-Ray Fluorescence Spectroscopy (XRF)

Failure Analysis
Environmental Scanning Electron Microscope (ESEM)
- *(25x-2500000x)*
- *Energy Dispersive Spectroscopy (EDS)*
- *In-situ Heating/Mechanical Testing*
- *Energy Dispersive X-Ray spectroscopy (EDX)*

Focused Ion Beam (FIB)
Wavelength Dispersive Spectroscopy
Stereoscope (10x-63x)
Optical Microscope (25x-1,000x)
Image Analysis
Transmission Electron Microscope (TEM)
Wire Pull, Bond Shear, and Die Strength Tester
Package Decapsulator
Ion Chromatograph
SIR Testing
Hollow Fiber Assessment
Real-time Solder Reflow Simulation
Component Popcorning Assessment
X-Ray Fluorescence Spectroscopy (XRF)

Opto-Mechanics Experimentation
Geometric Moire
Moire Interferometry
Microscopic Moire Interferometry
Shadow Moire
Infrared Fizeau Interferometry
Twyman/Green Interferometry

Virtual Qualification Lab
calcePWA
CADMP-II
calceFAST
Defects Webbook
PEMs Webbook
Accelerated Test Webbook
PWA Assembly Webbook
Integral Passives Webbook
PWA Failure Mechanism Webbook
Sensor Technology Webbook

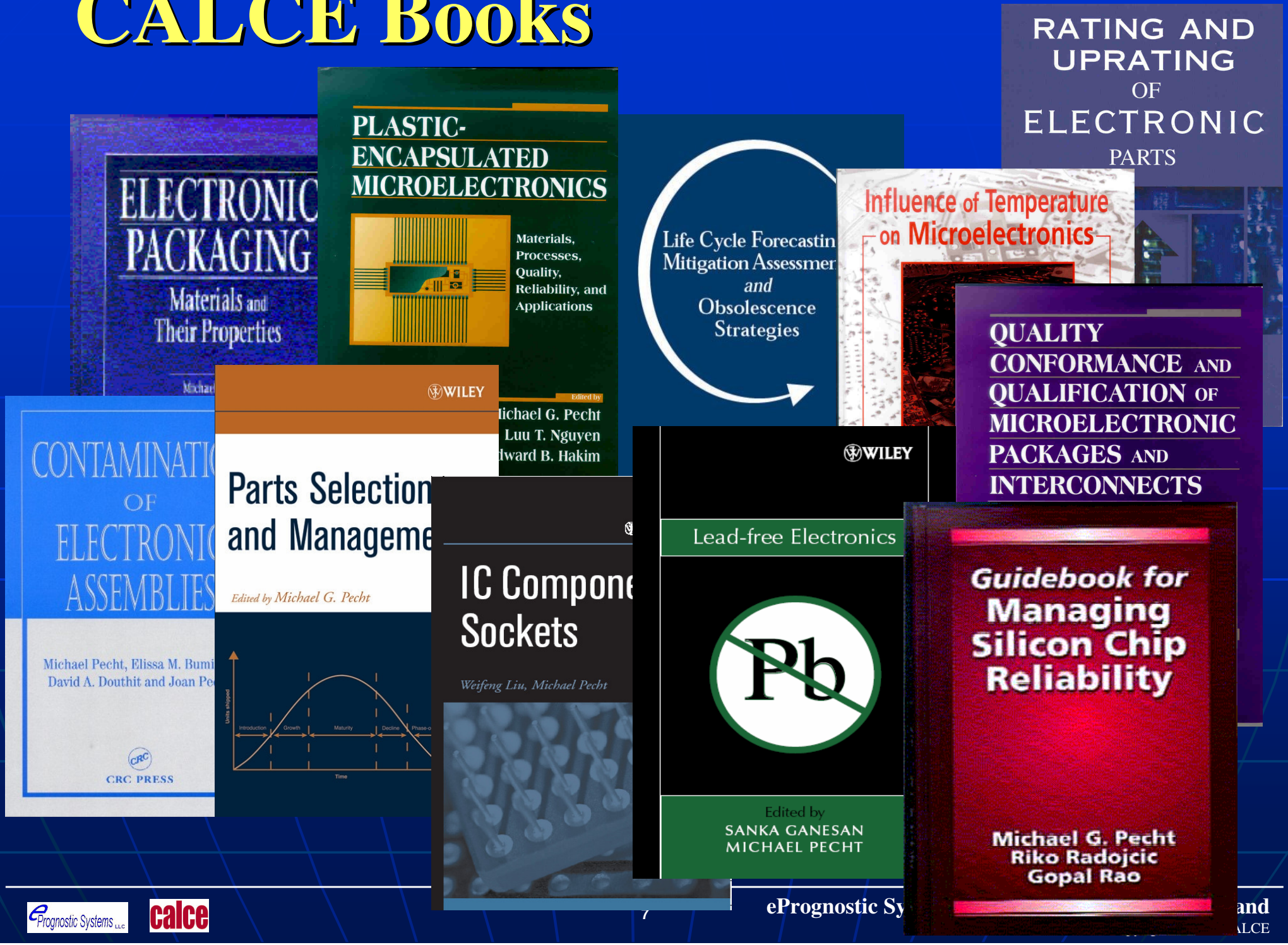
Electronic Testing and Analysis
Semiconductor Parameter Analyzer
Impedance Analyzer (1.86GHz)
Microcircuit Probe
Transistor and IC Curve Tracer
High Power Curve Tracer
LCR meter
Dynamic Signal Analyzer
Event Detectors
Electrometer
LCZ Meter
Thermal Inducing System (-80°C to 225°C)
Time Domain Reflectometer
Analog Oscilloscope
Power Supply
High Speed Digital Oscilloscope up to 20 GS/sec
Digital Communication Analyzer
Arbitrary Wave Form Generator
Function Generator
Contact Resistance Tester
Noise Figure Analyzer

Materials Characterization
Differential Scanning Calorimeter (DSC)
Micro-Mechanical Materials Tester
Thermo-Mechanical Analyzer (TMA)
Dynamic Mechanical Analyzer (DMA)
Creep Testing Equipment
Thin Film Analyzer (TFA)
Moisture Absorption System
Materials Test Systems (5 grams to 200 kg)
- *High-strain rate characterization (100/sec)*
- *Tests can be conducted in vacuum, inert or reactive atmospheres (-125°C to 300°C)*

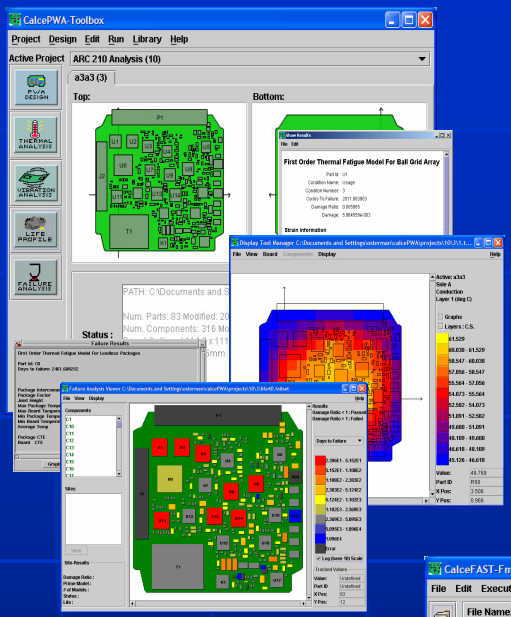
Micro-Hardness Tester
Micro-Fatigue Tester
Adhesion Tester

Copyright © 2007 CALCE

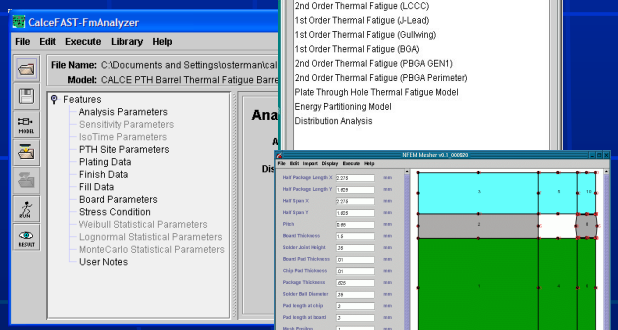
CALCE Books

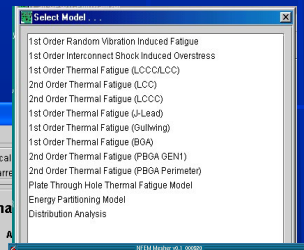

RATING AND UPRATING OF ELECTRONIC PARTS
ELECTRONIC PACKAGING
Materials and Their Properties
PLASTIC-ENCAPSULATED MICROELECTRONICS
Materials, Processes, Quality, Reliability, and Applications
Life Cycle Forecastin
Mitigation Assessmer
and
Obsolescence
Strategies
Influence of Temperature on Microelectronics
QUALITY CONFORMANCE AND QUALIFICATION OF MICROELECTRONIC PACKAGES AND INTERCONNECTS
CONTAMINATI
OF
ELECTRONI
ASSEMBLIES
Michael Pecht, Elissa M. Bumi
David A. Douthit and Joan Pe
CRC PRESS
WILEY
ichael G. Pecht
Luu T. Nguyen
dward B. Hakim
Parts Selection
and Manageme
Edited by Michael G. Pecht
Introduction
Growth
Maturity
Decline
Units shipped
Time
IC Compone
Sockets
Weifeng Liu, Michael Pecht
WILEY
Lead-free Electronics
Pb
Edited by
SANKA GANESAN
MICHAEL PECHT
Guidebook for
Managing
Silicon Chip
Reliability
Michael G. Pecht
Riko Radojcic
Gopal Rao

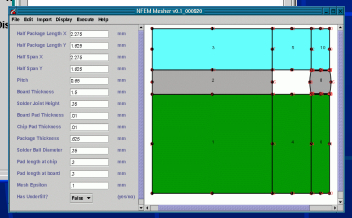
CALCE Physics-of-Failure Software
A Silicon-to-Systems Approach



calcePWA 5.2





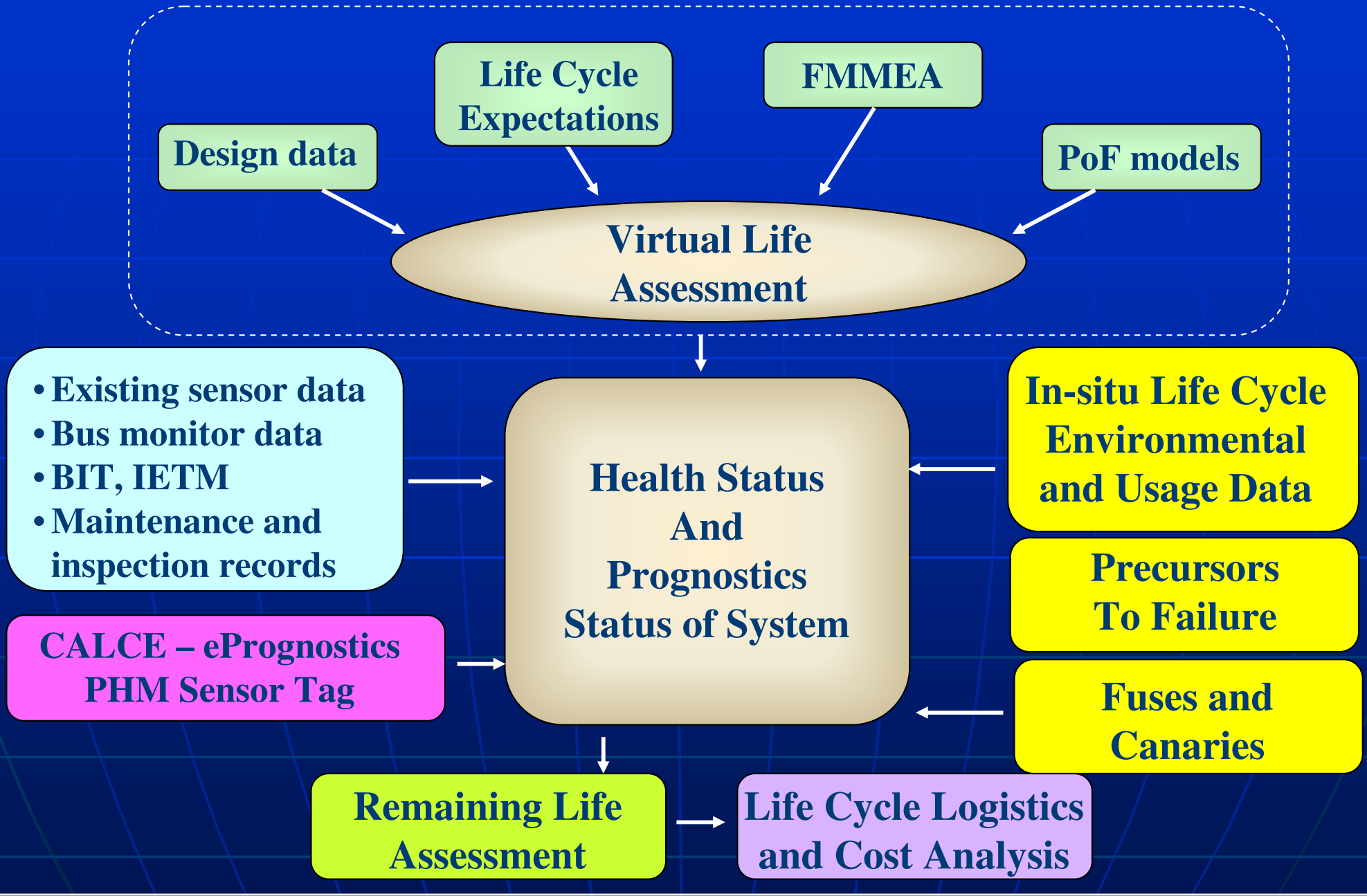


calceFAST 5.2

- The CALCE software is a simulation solution for assessing life expectancy (reliability) of components and printed wiring assemblies under anticipated life cycle loads.
- The software includes modules to conduct thermal and vibration response assessments.
- CALCE has extended prediction capabilities for Pb-free electronics.

Copyright © 2007 CALCE

CALCE Prognostics Methodology



Copyright © 2007 CALCE

Vehicle Component Prognostics in Vibration/Shock Environment

Alan Yu and Prof. Donald Barker

2007 CALCE PHM Consortium Meeting

Copyright © 2007 CALCE

Copyright © 2007 CALCE

Army AMSAA –CALCE PHM Project Demonstration System

Copyright © 2007 CALCE

Project Motivation and Approach

Motivation

- Improve reliability of military vehicles and equipment operating in harsh environments
- Further demonstrate ability of LCM process to accurately predict remaining life

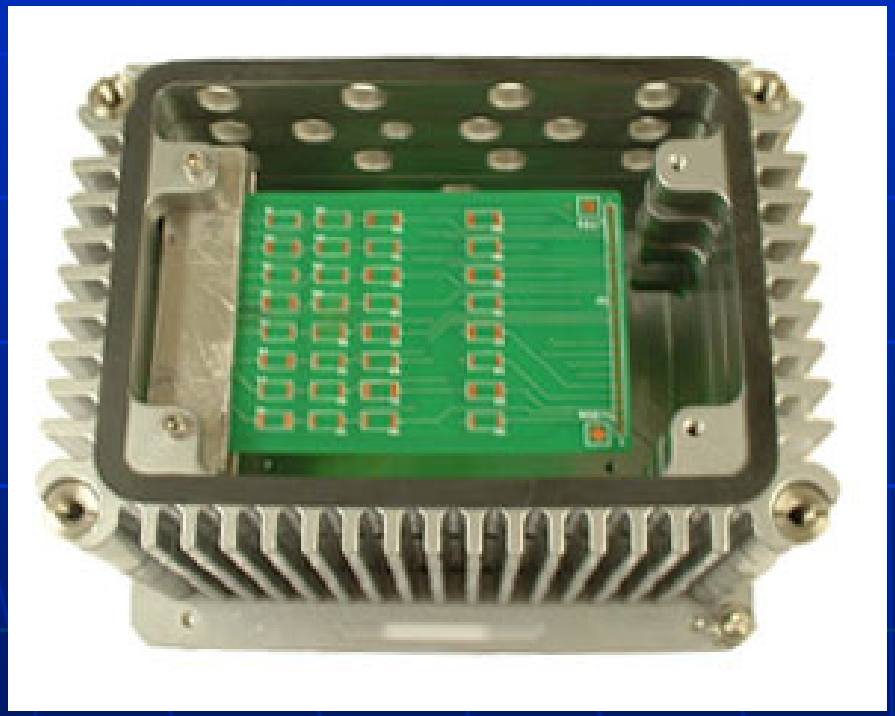
Approach

- Collect data from test vehicles on various terrains during ongoing drive tests at Aberdeen Test Center (ATC) and Yuma
- Identify key parameters to monitor and assess
- Calculate damage accumulation from load history
- Compare life, and remaining life predictions with field failures

Copyright © 2007 CALCE

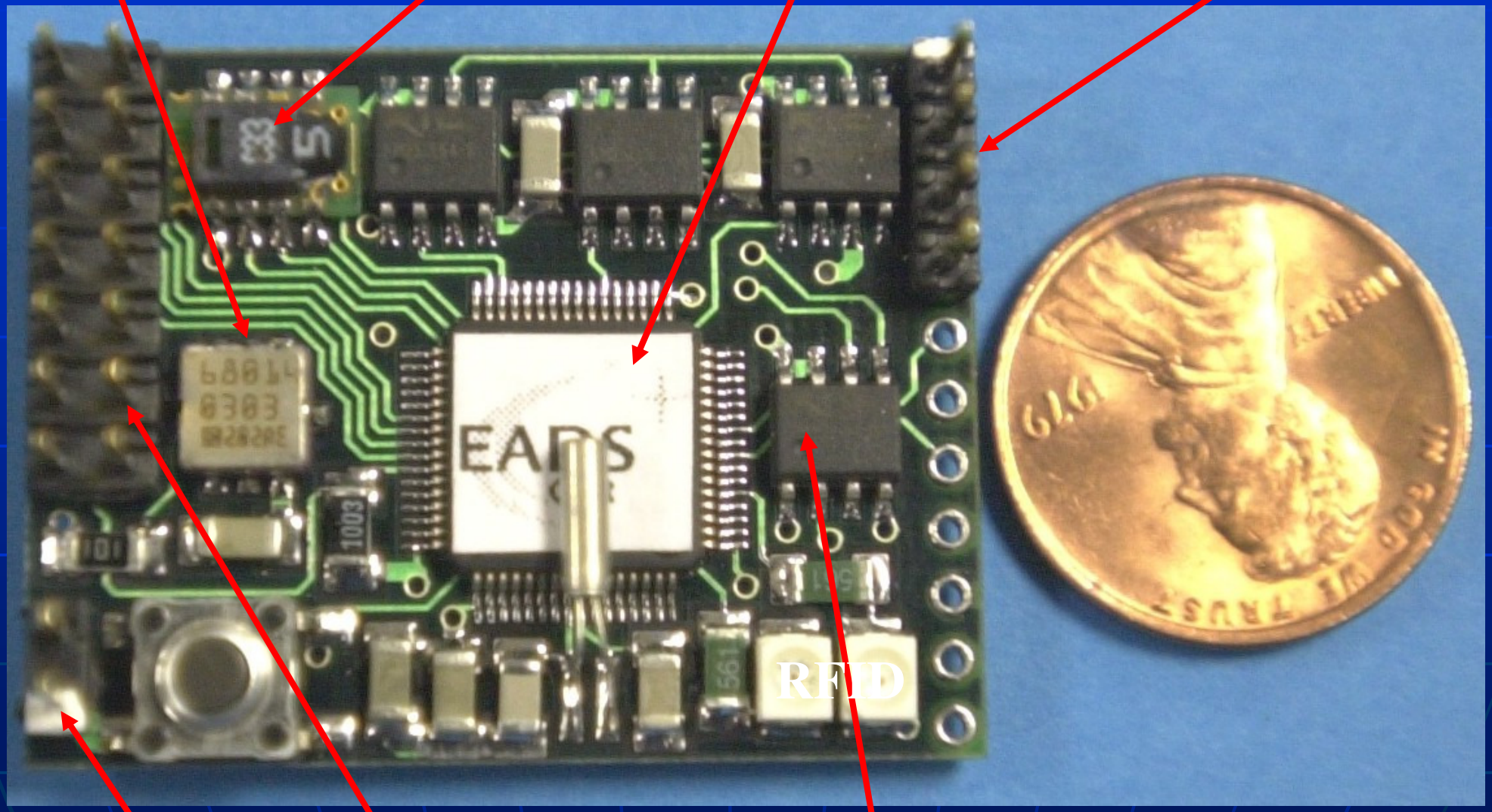
PWB Test Design

- Cantilevered 2512 resistor board



Copyright © 2007 CALCE

EADS - CALCE HUMS and Prognostics Project

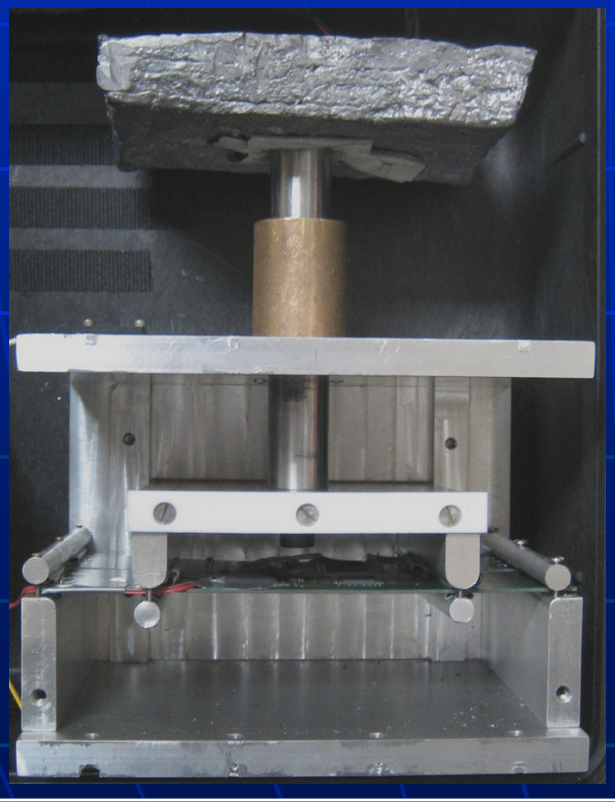


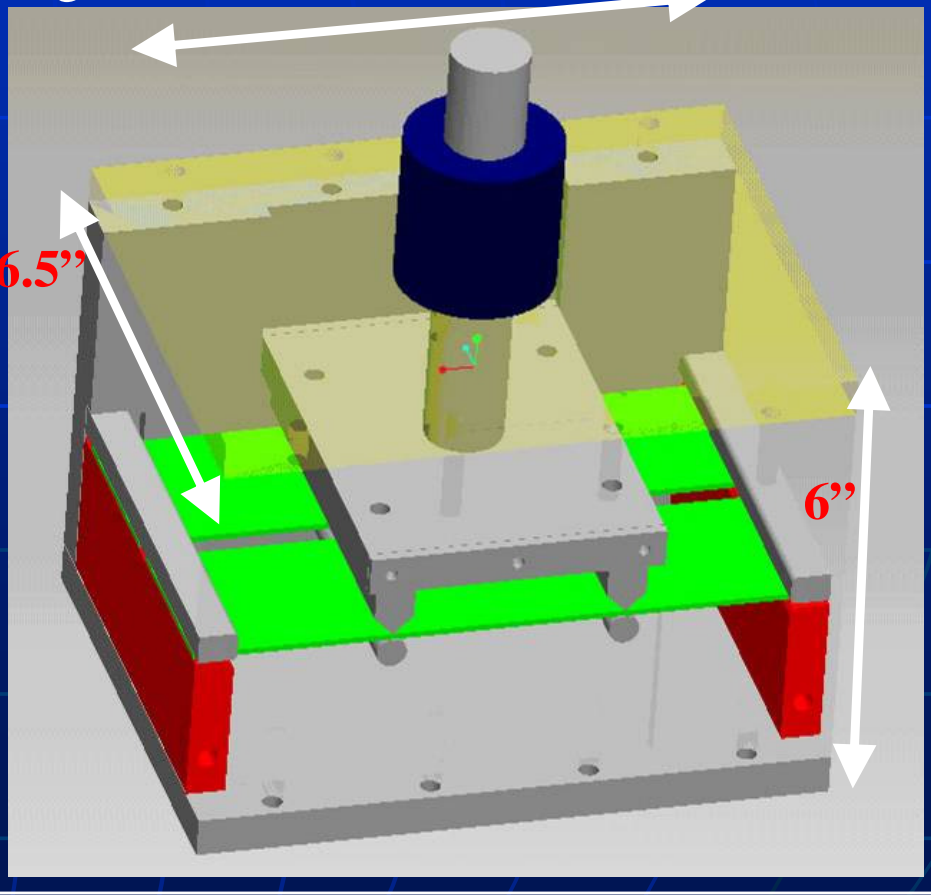
Copyright © 2007 CALCE

Current Testing Setup

Test apparatus – bending fixture

- 4-point bending, constant strain across board test area
- 1.5” max amplitude vertical motion range
- Max strain: 4000 µstrain +
- Weight added to increase dynamic loading on PCBs
- Tests 2 PCBs at simultaneously



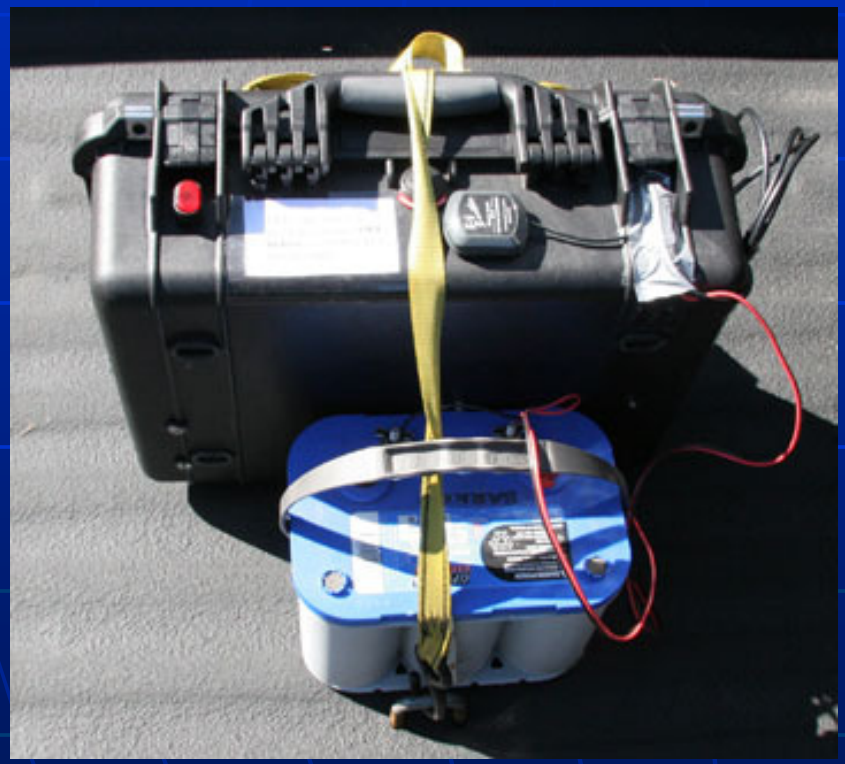


Copyright © 2007 CALCE

Preliminary Testing

Setup

- Case secured to bed of a F-350 Super Duty truck with 12V battery power source



Copyright © 2007 CALCE

Preliminary Testing

Environmental loading – random vibration

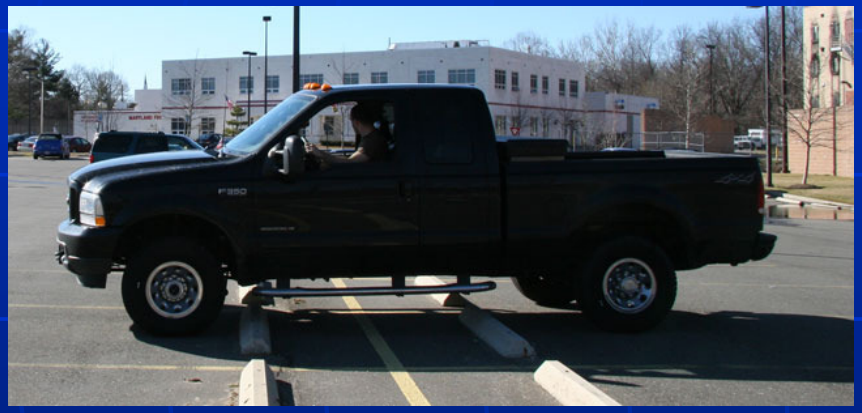
- Many test runs conducted on paved roads around Maryland, some roads more poorly maintained than others (searched out pot holes, speed bumps, and rough roads)
- No failures produced by paved roads in poor or good condition
- Strain levels produced by paved roads too low of amplitude to induce any significant fatigue damage in reasonable amount of time
- Vehicle suspension filters out higher frequency loading
- **Harsher testing conditions needed to produce failure data**

Copyright © 2007 CALCE

Preliminary Testing

Environmental loading – shock

- Shock testing on parking curbs and speed bumps near campus
- Significantly higher strain levels

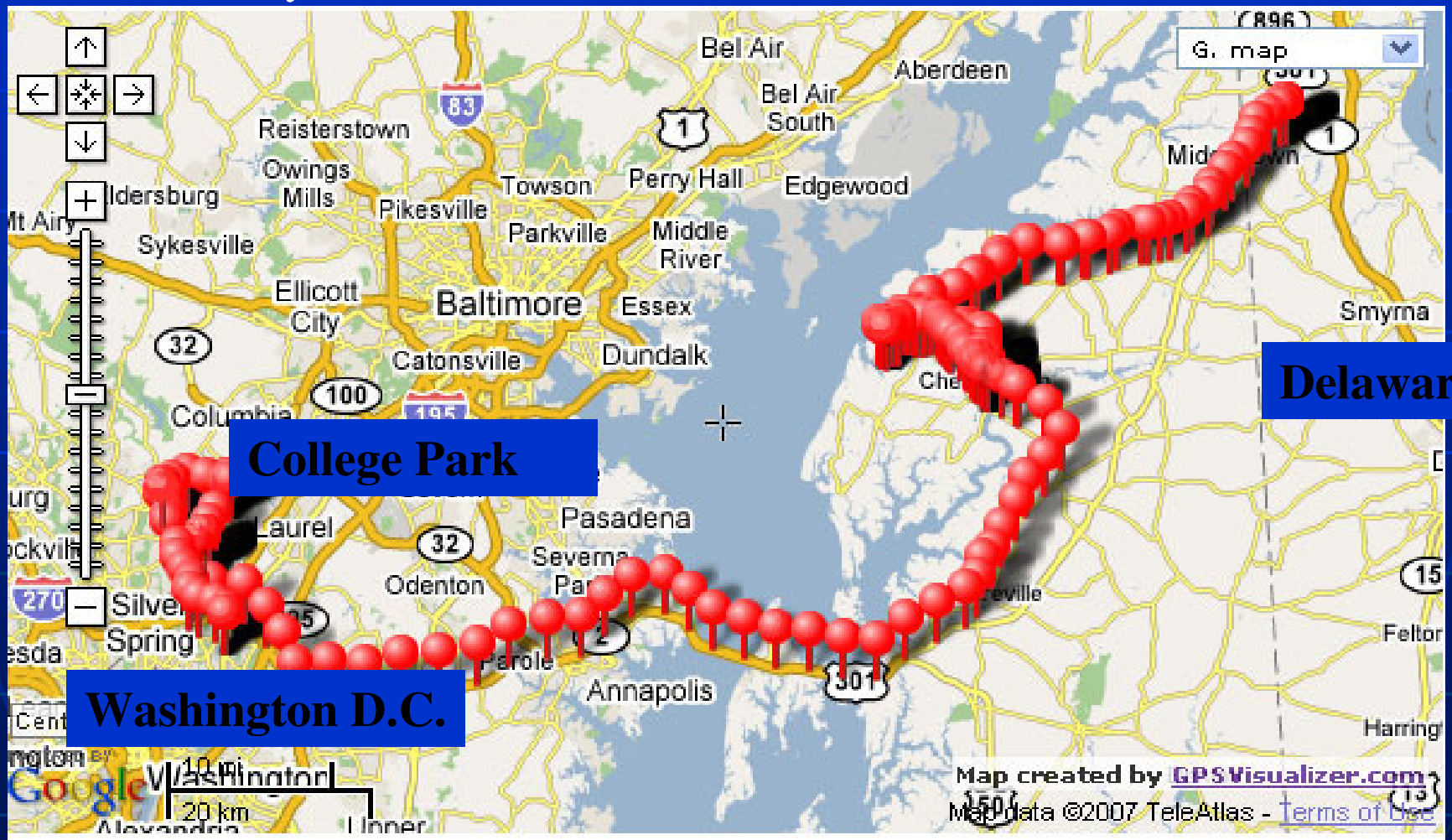


Copyright © 2007 CALCE

Preliminary Testing

Environmental loading – random vibration

- 87 hour monitoring of road trip / misc. driving on paved roads
- Continuously recorded strain, acceleration, and GPS

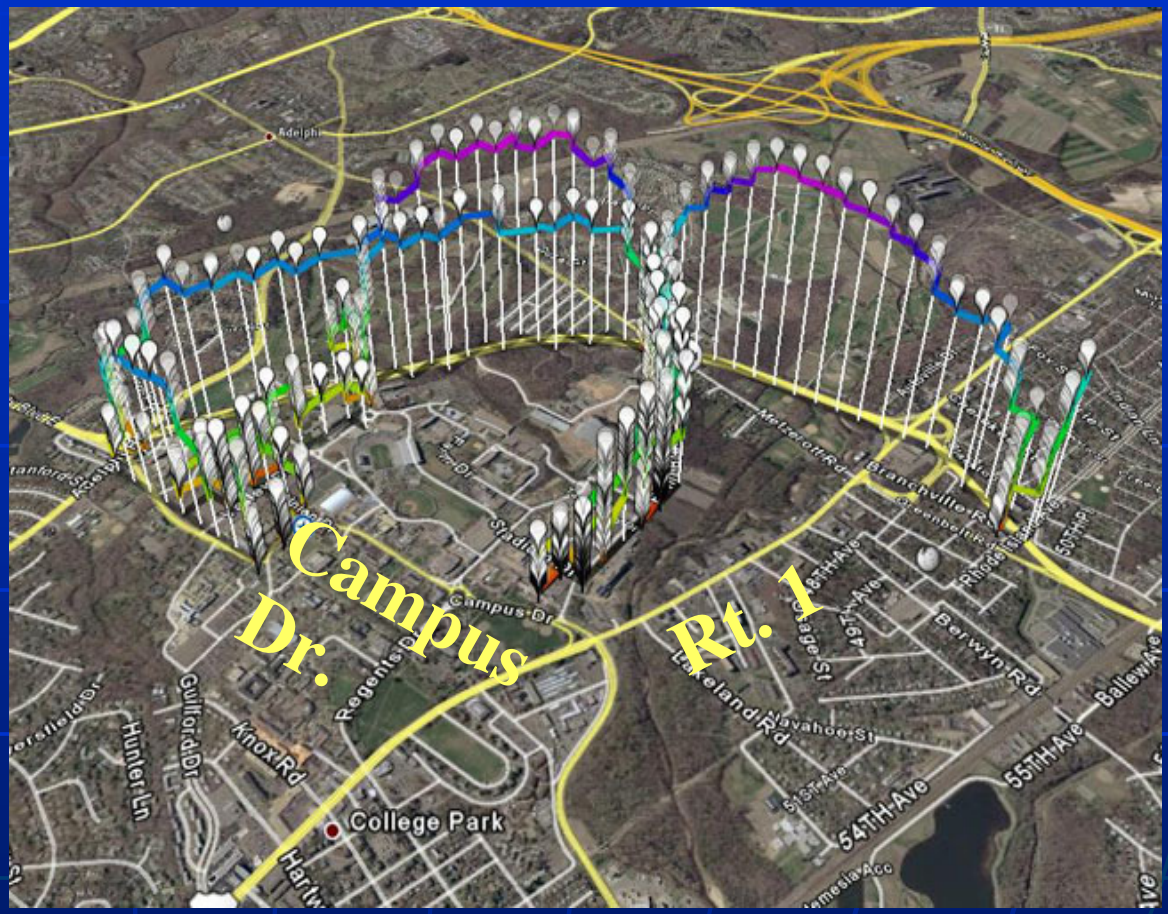


Copyright © 2007 CALCE

Data Processing and Analysis

Viewing GPS data

- GPS data is imported into MATLAB where it can be combined with accelerometer, strain, or other data into a proper format and common sampling rate.
- Data is then converted into GPX format.
- GPX file is converted into a Google Earth kmz file for viewing data over terrain.



Speed vs. Location

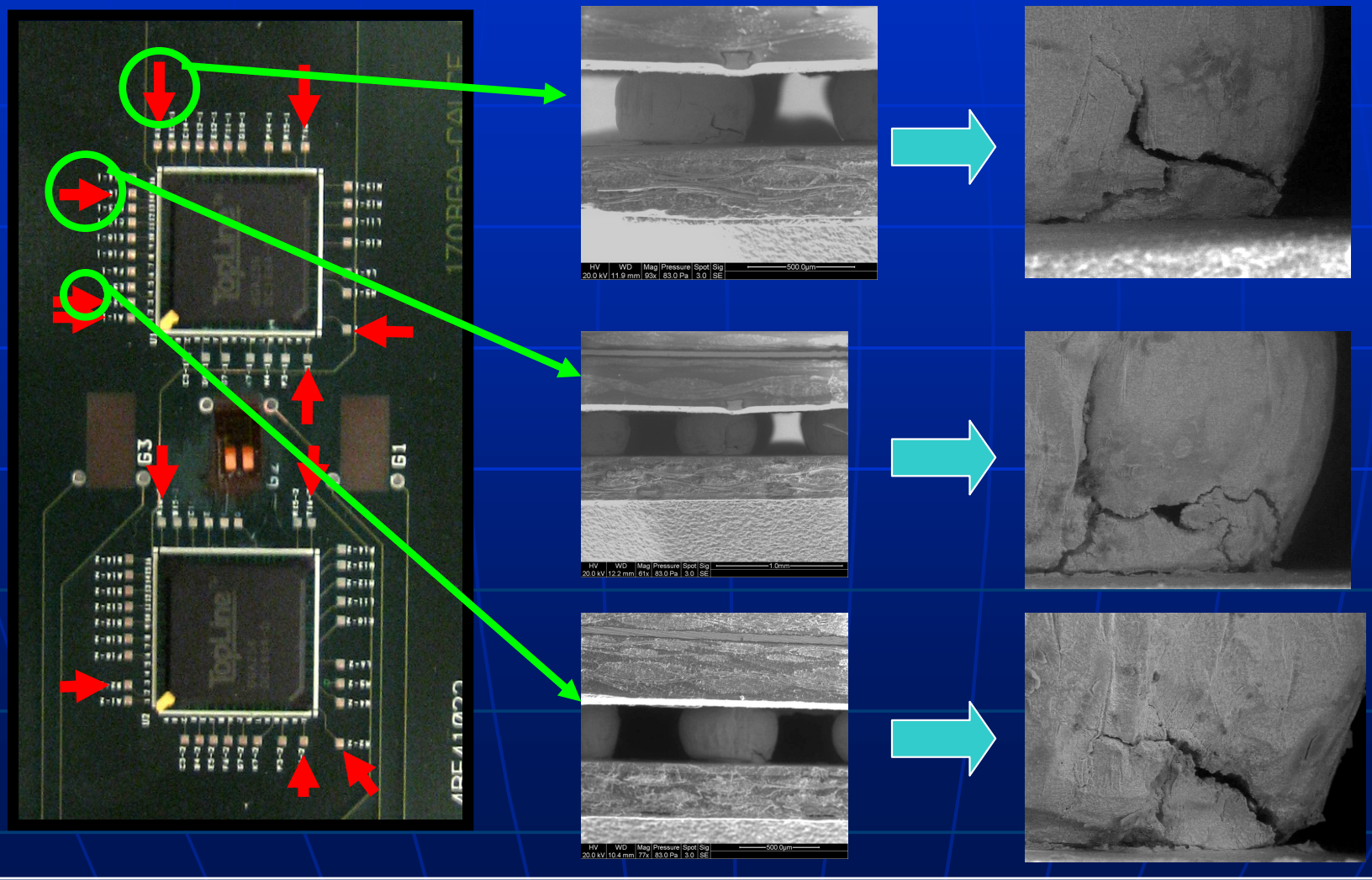
Data can be viewed over terrain in Google Earth

Copyright © 2007 CALCE

Failures from Preliminary Testing

BGA failures from shock testing

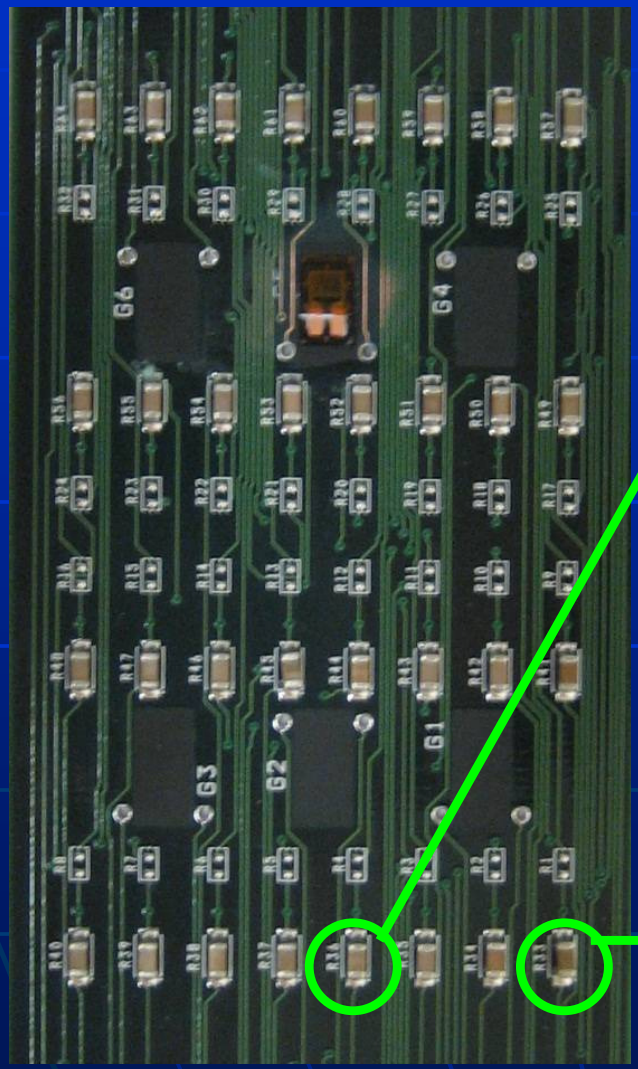
- Most of the corner pins on the BGAs failed

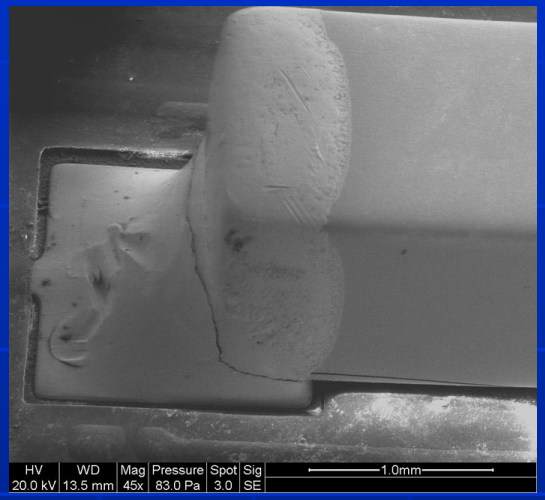


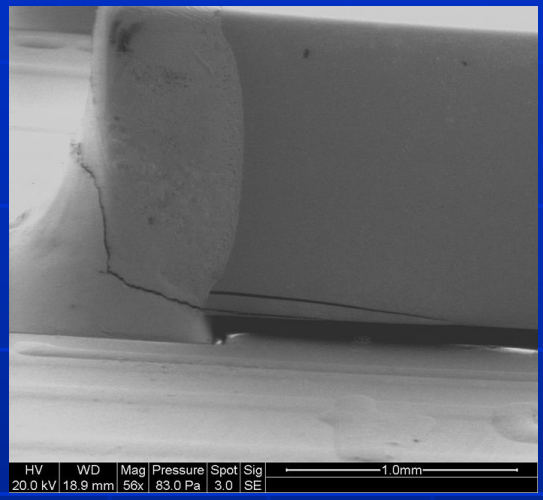
Copyright © 2007 CALCE

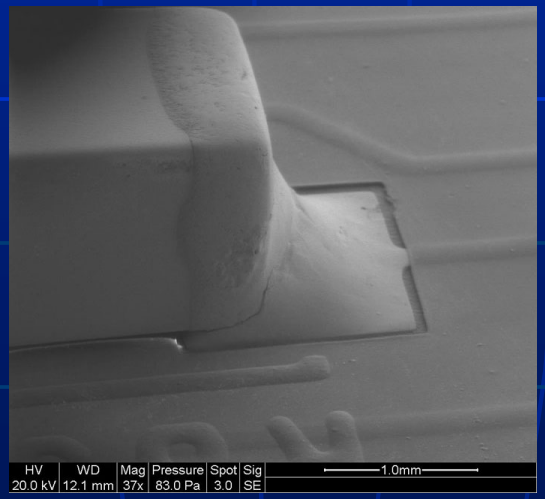
Capacitor Failures from Preliminary Testing

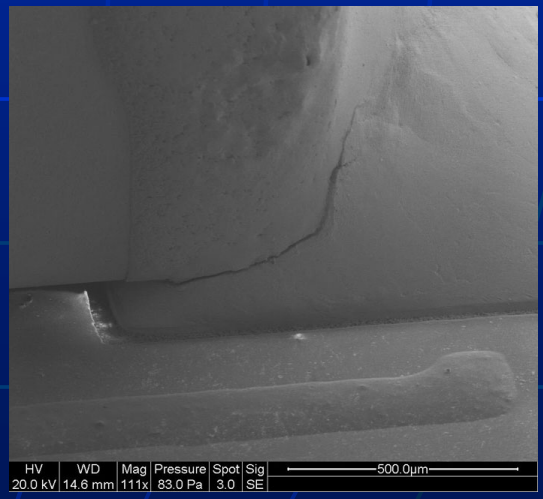
Two capacitor failures were found after shock loading











Copyright © 2007 CALCE

ePrognostic Systems

PHM-Tag

CALCE – ePrognostic Systems Tag Development

- CALCE and ePrognostic Systems are developing and test a novel **PHM-Tag**.
- This tag is to be used to assess equipment environments, equipment health and to provide prognostics for condition-based maintenance.

Copyright © 2007 CALCE

Army – CALCE – ePrognostic Systems - SWORDS PHM Project

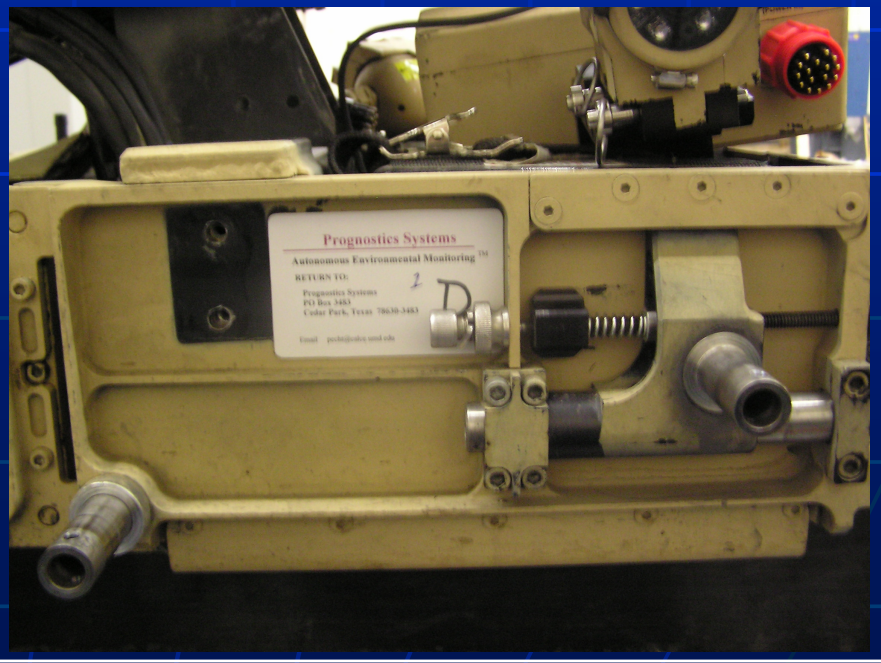
Copyright © 2007 CALCE

CALCE – ePrognostic Systems Tag

- Dimensions: 86mm x 55mm x 2mm (3.4” x 2.2” x 0.06”)
- Memory storage for 720 readings (load-stress readings, date-time)
- It can be programmed to start at a later target date-time
- Programmable data collection in a continuous mode with programmable data sampling intervals
- Programmable preset load-stress limits, both high and low.
- Programmable data collection upon limit violation, including date-time stamp. Data can be collected only when load-stress limit is being violated, or at the start of a load-stress violation.
- Mountable in various modes, including an adhesive manner.
- Active RFID write and readable, with limited distance to minimize system interference.
- Completely OPEN-architecture
- Reusable
- Suitable for military temperature range applications
- This tag has undergone testing at Army-Aberdeen Proving Grounds.

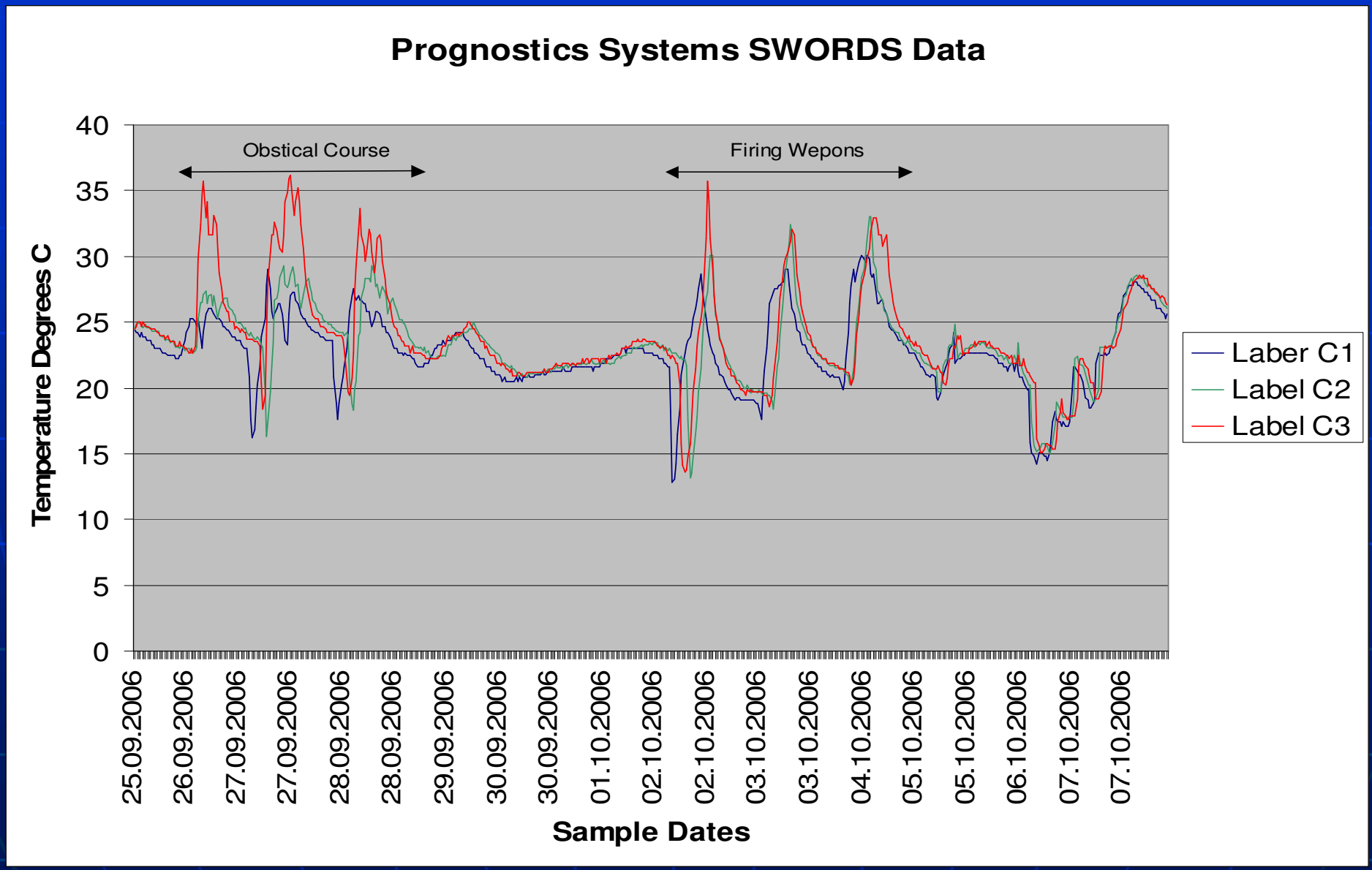
Copyright © 2007 CALCE

PHM-Tags on SWORDS



Copyright © 2007 CALCE

ePrognostic Systems PHM - Tag Data



Copyright © 2007 CALCE

CALCE – ePrognostic Systems Tag Testing

- We are interested in testing 200 of our PM-Tags on equipment for about 3 to 6 months. We would help in setting this up and in monitoring.
- There is value in getting some good statistically significant data to show how the PHM-Tags work and how the information obtained can be used.

Copyright © 2007 CALCE

CALCE – Prognostic Systems Tag Development - Next Steps -

- Military level qualification and accelerated life testing
- Add shock and humidity sensing, programming and data analysis
- Incorporate tamper feature & record tamper date-time.
- Expand memory to enable on-Tag autonomous analysis
- Incorporate CALCE software to reduce data into distributions.
- Include software for failure precursor analysis.
- Provide variable RFID read/write distance
- Use more novel batteries to increase lifetime to 2 years

Copyright © 2007 CALCE

ePrognostic Systems

PHM-Tag