Center for Advanced Life Cycle Engineering (CALCE)

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http://www.calce.umd.edu

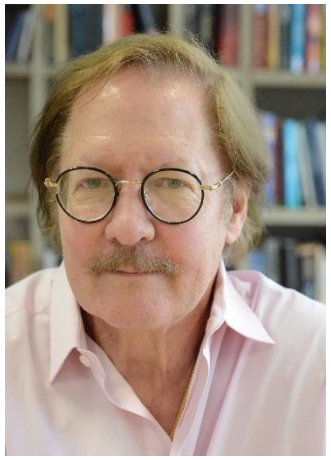
CALCE Clients

- ABB Switzerland Ltd.
- ACell, Inc.
- ACC Electronix
- Advanced Bionics
- Aerojet Rocketdyne
- Agilent Technologies, Inc.
- Allergan
- America II Electronics, Inc.
- American Panel Corporation
- Amazon Web Services
- Anadigics, Inc.
- Ansaldo STS USA, Inc.
- Applied Biometrics
- AprilAire
- ASML
- AST
- ATV Semapp
- Austria Microsystems AG
- Avaya Global Operations
- BAE Systems Electronics & Integrated Solutions
- Baker Hughes Inc.
- Bartlit Beck Herman
- Beijing Weibu Technology Limited Liability Company
- Bloomberg
- Boeing Co.
- Bombardier Aerospace
- Butterfly Networks
- Celestica International
- Chrysler Corp.
- Club
- CNN
- Coch
- Colli
- Cont
- Curti
- Cum
- CSX
- Dakt
- Defe Activ
- Dell,
- Delp
- Dow
- Dow
- DFR
- Edmu
- Embr
- Emerson
- Electrospec, Inc.
- EMC Corp.
- Fairchild Controls Corp.
- Finisar
- FirstTissues
- Fourth Dimension
- Fujitsu Network Communications
- GE Healthcare Technologies
- General Dynamics Advanced
- Keysight
- Microsoft Corp.
- Milwaukee Power Tools
- MKS Instruments, Inc.
- Moog Inc.
- MSA
- MDS Coating Technologies
- NASA Glenn Research Center
- NASA Goddard Space Flight Ctr
- e Center
- rp.
- Corp.
- Samsung Electronics Co.
- Sandia National Laboratories
- Savenia Labs.
- Schlumberger Oil Drilling Services
- Seagate
- Selex Electronics Systems Ltd
- Silicon Powers
- SpaceQuest
- SORAA
- Souriau
- Stratasys, Inc.
- Stryker
- Stanley Black and Decker
- Sun Metals
- Sunpower
- Team Corp.
- TEKELEC
- Telcare, Inc.
- Trilumia.
- Teradyne, Inc.
- Tessera
- Tintronics Industries
- Toyota Research Institute of N.A.
- Triumph
- TU CIC Virtuhcon
- U.S. Army ARDEC
- U.S. Army CECOM
- U.S. Army Research Lab.
- Unison Industries
- Universal Lighting Technologies
- Vertiv
- Waites
- Whirlpool
- X-Wave

- **Consumer and mobile products**
- **Telecommunications and computer systems**
- **Energy systems (generation/storage/distr)**
- **Industrial systems**
- **Automotive systems**
- **Aerospace systems**
- **Medical systems**
- **Defense systems**
- **Equipment manufacturers**
- **Government Labs and Agencies**

Technical Consulting with CALCE Principal Investigators

Expertise list at https://calce.umd.edu/our-team



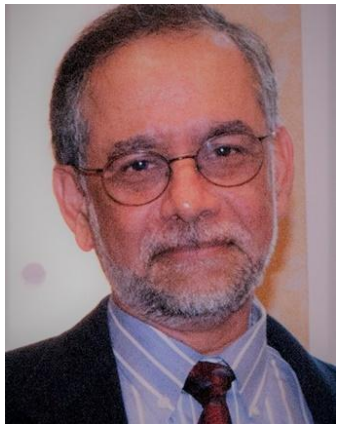
Michael Pecht

Michael Osterman

Michael Azarian

Diganta Das

Robert Utter



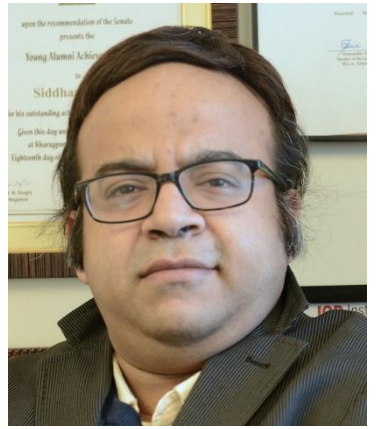
Abhijit Dasgupta

Patrick McCluskey

Bongtae Han

Peter Sandborn

Damena Agonafer



Siddartha Das

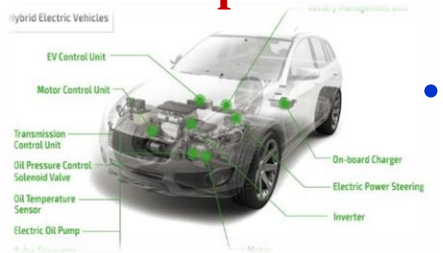
CALCE at University of Maryland
Over 40 Years of CALCE Support of the Electronic Industry

- Research, test and consulting services (contracts through UMD, lab services, consortia membership)
- Over 800 research projects, $120 million in research funding, and 1000+ published articles) for design, manufacture, life assessment and life management of electronics components, products and systems
- Continuing learning opportunities (more than 300 webinars, 100+ keynotes at conferences, 200+ short courses)
- Skilled engineers (over 300 Ph.D. and 500 M.S. degrees) with sophisticated problem solving skills for design, manufacture and test of reliable products that meet the targeted applications
- Over 500 practicing engineers working for organizations such as Apple, Dell, Google, Honeywell, Intel, Microsoft, NASA, Northrop Grumman, Samsung and Schlumberger

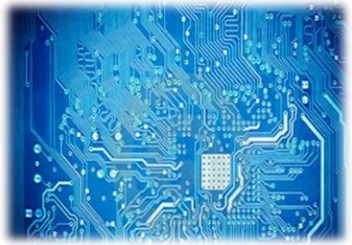
CALCE Research Activities

Reliable, Safe, Secure Microelectronic Systems

Military & Aerospace



Automotive

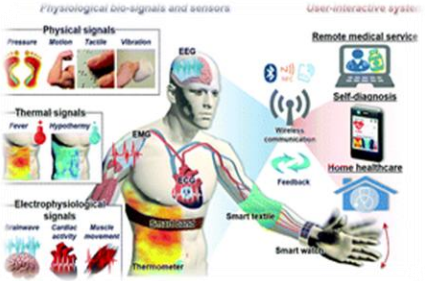


Computing and Data Systems

Servers and HPCs

- **Research Consortia**
  - Shared basic research projects, software access, seminars, consulting, discounted test services, failure analysis
- **Test Services and Failure Analysis**
  - Design review, technical consulting, simulation-assisted and testing-based qualification, material and product testing, supply chain management, root cause assessment
- **Contracts**
  - Research & service contracts with negotiated terms with UMD.
- **Education**
  - Degree and certificate programs, on-site customized professional development courses, web-based workshops, internships, community college outreach, regional consortia.
- **Standards & Roadmaps Development**
  - Standards and Roadmap development through societies and organizations such as IEEE, ASME, Semi, IPC, MIL, SAE

Industrial Systems



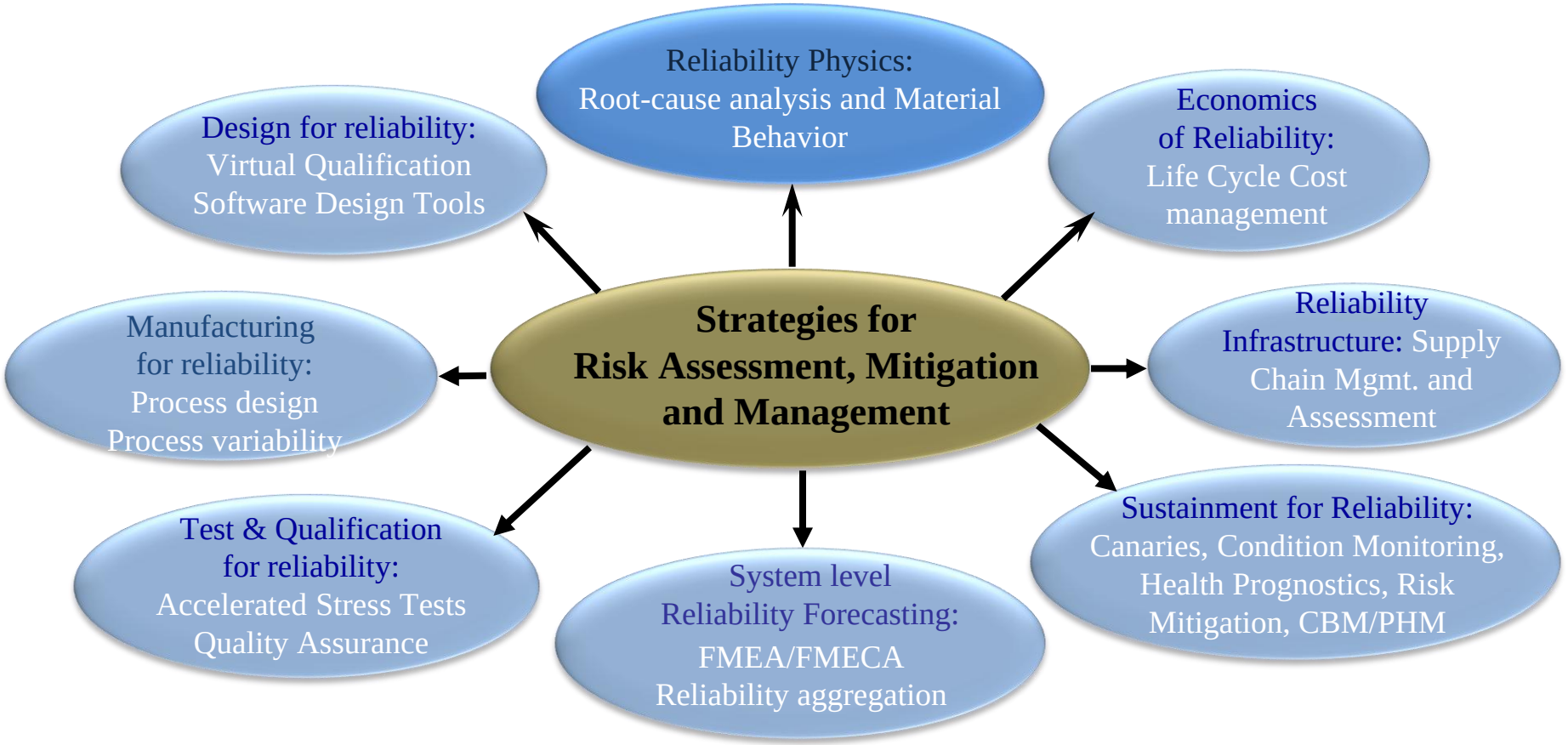
Healthcare systems

Communications

Energy systems

CALCE Research Areas

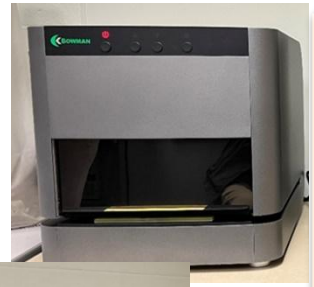
Providing a knowledge and resource base to support the development and sustainment of competitive products



Convergence of Reliability-Physics (RP) and Artificial Intelligence (AI)

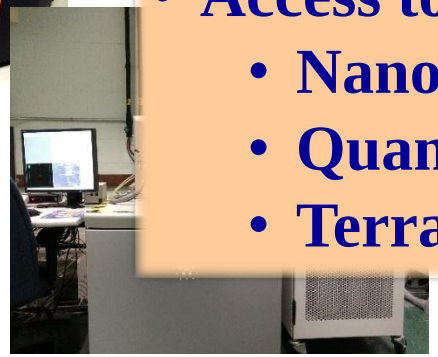
CALCE Facilities: Extensive Test and Metrology Labs

XRF



FTIR

DMA & TMA



ESEM

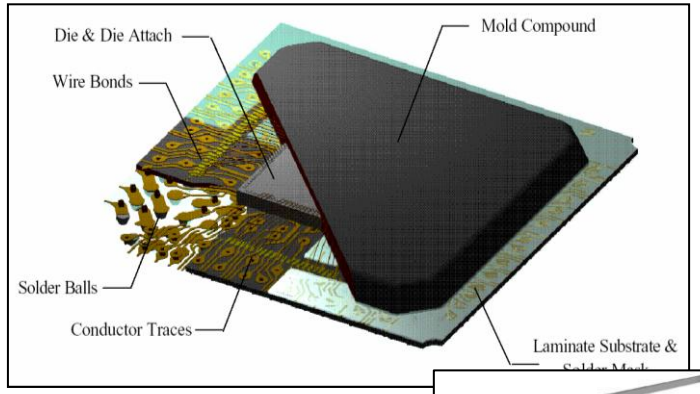
- **Materials Metrology**
- **Virtual qualification: Multi-physics, multi-scale co-design**
- **Security analysis and testing**
- **Thermal assessment and management**
- **Physical qualification: Environmental/Accelerated Testing**
- **Sample preparation and failure metrology**
- **Non-destructive evaluation and metrology**
- **Opto-mechanics test and metrology for model validation**
- **Electronics/Photonics testing and metrology**
- **Education and workforce training**
- **Access to other Clark School facilities:**
  - **NanoCenter**
  - **Quantum Tech Center**
  - **Terrapin Works (Additive Manufacturing)**

High Temperature Storage

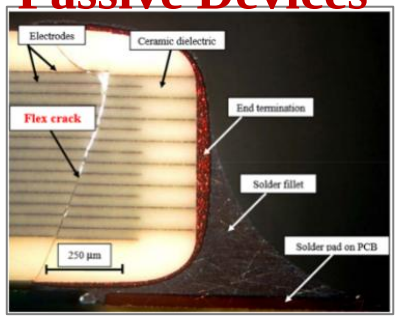
High-G Drop Testing (100,000 Gs)

Physics of Failure Based Reliability of Electronic Devices and Interconnects

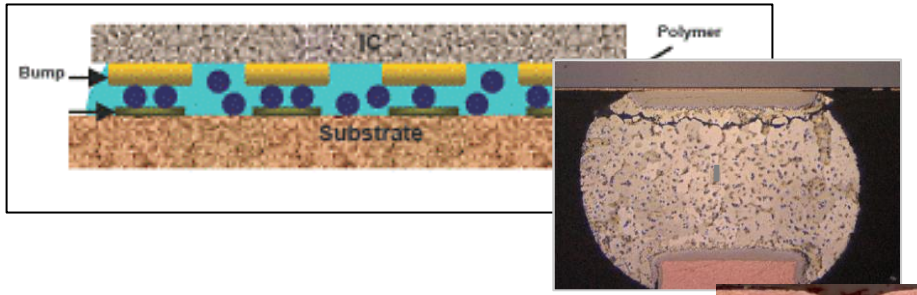
Active Devices

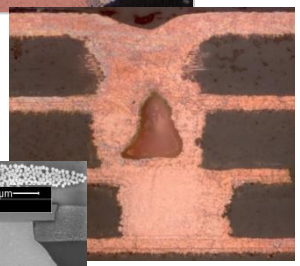


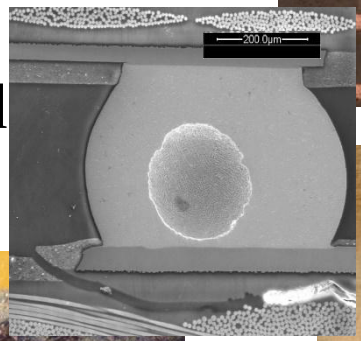
Passive Devices

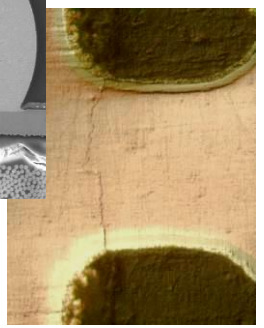


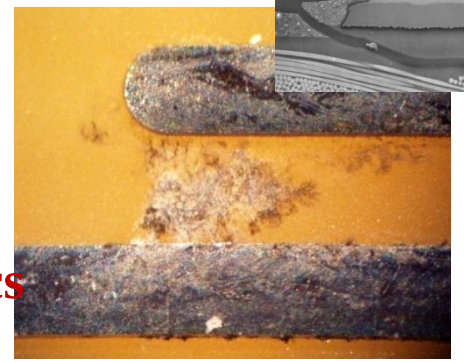
Interconnects







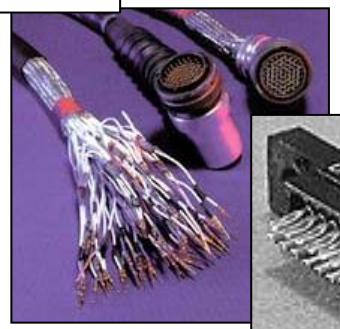


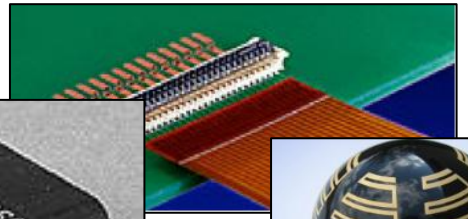


Reliability models and acceleration models can use physics-based and data-based models

Batteries

Adhesives





Cables & Connectors

Printed Electronics

High-Density Substrates

$$TTF = F(geometry, material, environment)$$

CALCE Life Cycle Reliability and Safety

Design for Reliability and Safety

- Parts selection
- Failure modes and mechanisms
- Derating
- Multiphysics analysis
- Materials metrology
- AI-assisted design

Manufacturing

- Process modeling and yield mgmt.
- Process monitoring and control
- Process metrology
- Industrial AI
- Screening and burn-in strategies
- Manufacturing metrology

Testing and Verification

- AI - physics of failure based accelerated test planning
- Failure metrology
- Uncertainty assessment
- Safety evaluation
- RUL assessment
- Security assessment

Deployment

- Performance metrology
- Anomaly detection
- Diagnostics and classification
- Health monitoring
- Warranty analysis

Maintenance

- Fault diagnostics
- Root cause analysis
- Prognostics
- Predictive and condition-based maintenance
- Sustainment

End-of-Life

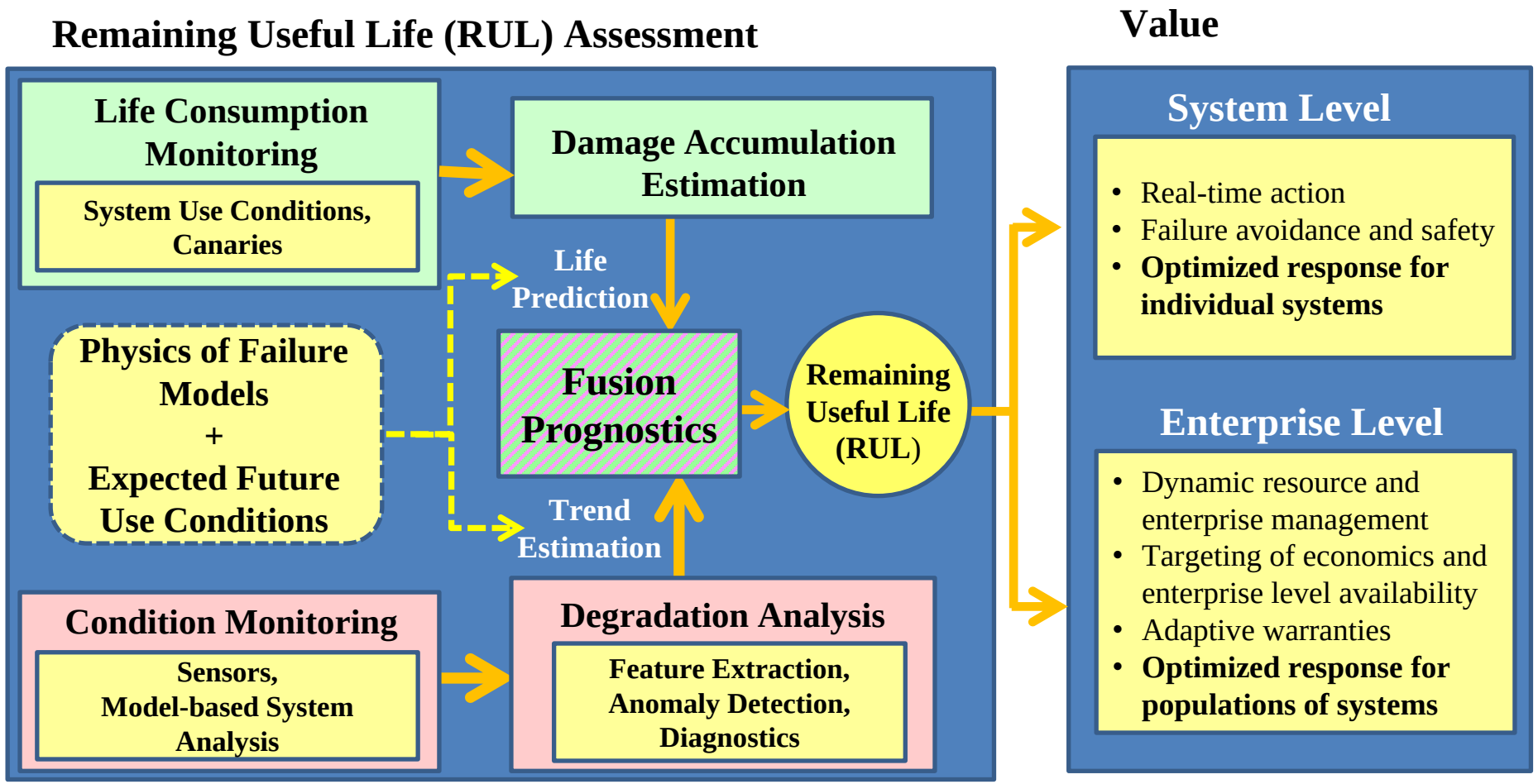
- Recycle
- Reuse
- Repurpose
- Disposal

Supply-chain and life cycle cost management

Disruption management
(Supply chain risk, Allocation, Security)

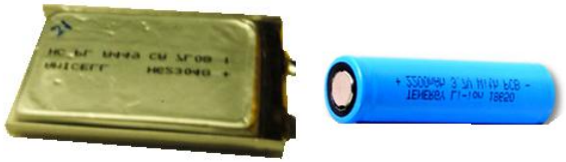
Compromise management
(Obsolescence, Counterfeit)

Prognostics and Health Management Approach



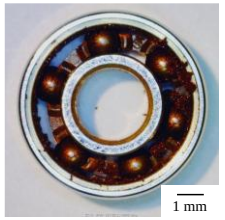
Examples of CALCE PHM Applications

Batteries, Capacitors

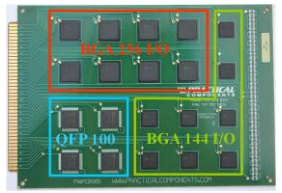


Coils

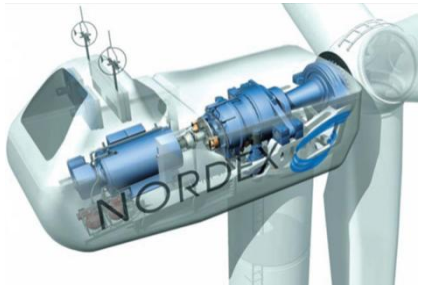
Gearboxes, Bearings, Machinery



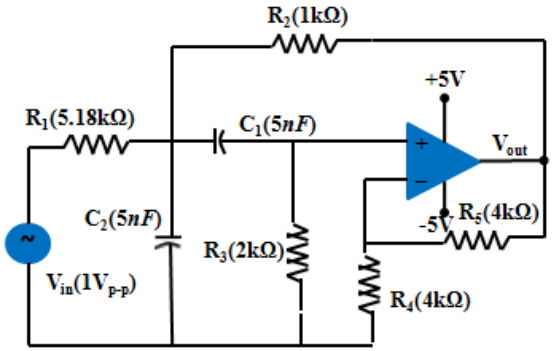
PCBs



Wind Turbines

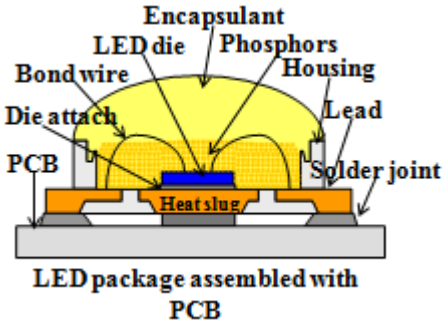


Circuits



IGBTs

LEDs



Avionics

Aircraft

MarineVessels

Ground Vehicles

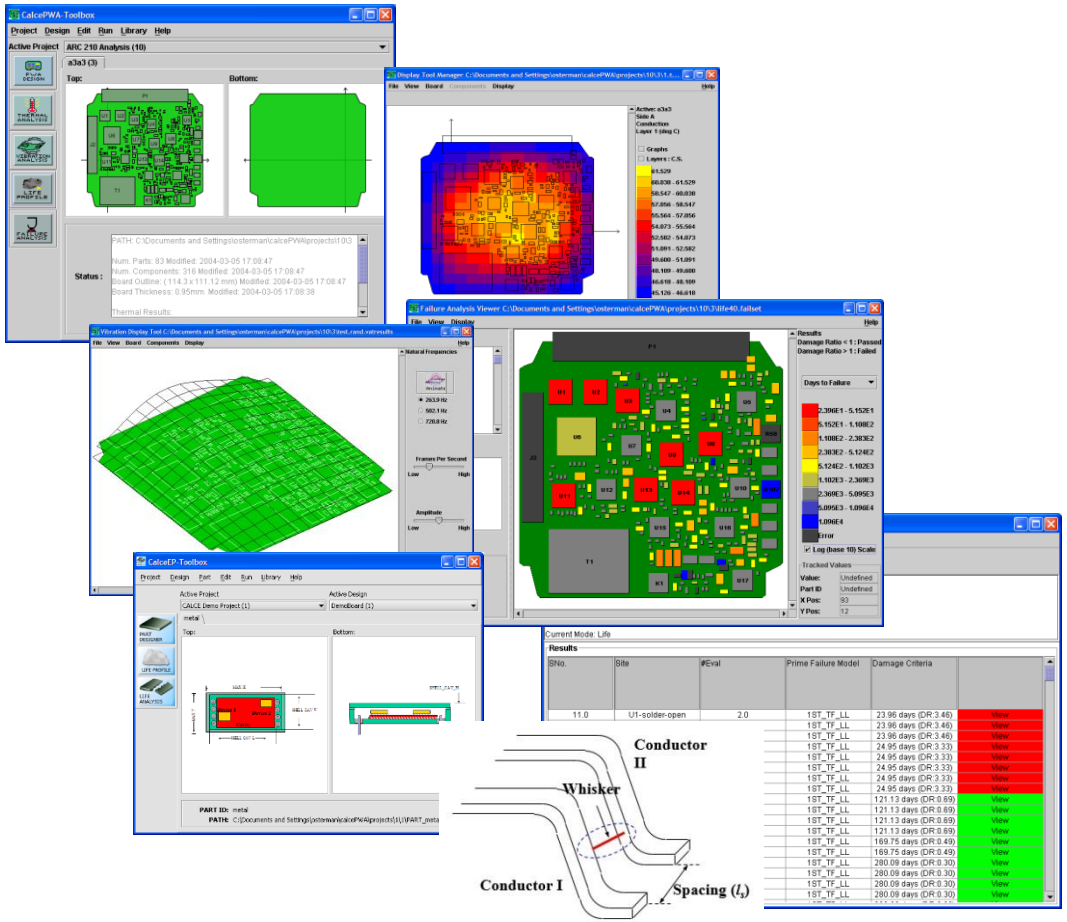
Fee-for-Service

- Battery Characterization
  - Capacity Measurement
  - Capacity Fade
  - Impedance Measurement
  - Construction Analysis
- Failure Analysis
  - Board Solder Interconnects
  - Passives and Connectors
  - Active Devices
- Material Characterization
  - Board Construction
  - Solder Joint/Intermetallic Formation
  - CTE Measurements
  - Plating Thickness
- Simulation/Modeling
  - CALCE SARA Software
- Testing
  - Mixed Flowing Gas
  - Flower of Sulfur
  - Vibration
  - Drop
  - Temperature/Humidity
  - Temperature Cycling
- Training
  - Failure Analysis
  - Physics of Failure Assessments
  - Design Reviews
  - Supplier Assessment
  - Prognostics and Health Monitoring

CALCE Simulation Assisted Reliability Assessment Software

https://calce.umd.edu/calce-simulation-assisted-reliability-assessment-sara-software

Downloads/Activations 2024/25: 90



Assembly, Package and Device Failure Assessment Modules

Body Module Computer

83% reduction in design issues

>10% reduction in time to market

Engine Controller

Virtual qualification of engine controller identified life limiting design issues

Radio System

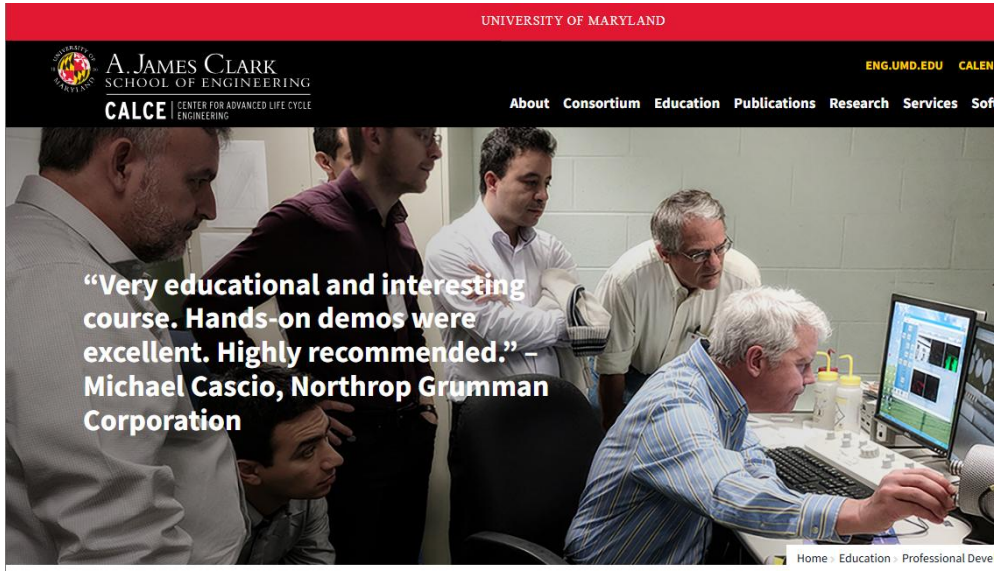
Identified design life issue saving customer an estimated $27 million dollars

Software is available for free,
Members get early access to feature and data sets
Training is available

CALCE Short Courses

https://calce.umd.edu/professional-development-courses

- Accelerated Product Qualification.
- Counterfeit Parts Detection Using SAE AS6171
- Component Documentation and Supply Chain Management for Counterfeit Avoidance
- Critical System Sustainment
- Electronic Part Obsolescence Forecasting, Mitigation, and Management
- Electronic Product and System Cost Analysis.
- Failure Analysis of Electronics
- High-Temperature Electronics
- Lead-Free Readiness
- Light Emitting Diode (LED) Reliability
- Lithium Ion Battery Testing and Reliability
- Reliability Science
- Reliability of Electrical Connectors and Contacts
- Prognostics and Health Management
- Virtual Qualification and Reliability Assessment



Symposium on Counterfeit Parts and Materials 2025

College Park, MD, USA
June 24 - 26, 2025

For More Information

Submit Your Abstracts!

Reliability Science Symposium at University of Maryland College Park, MD, USA

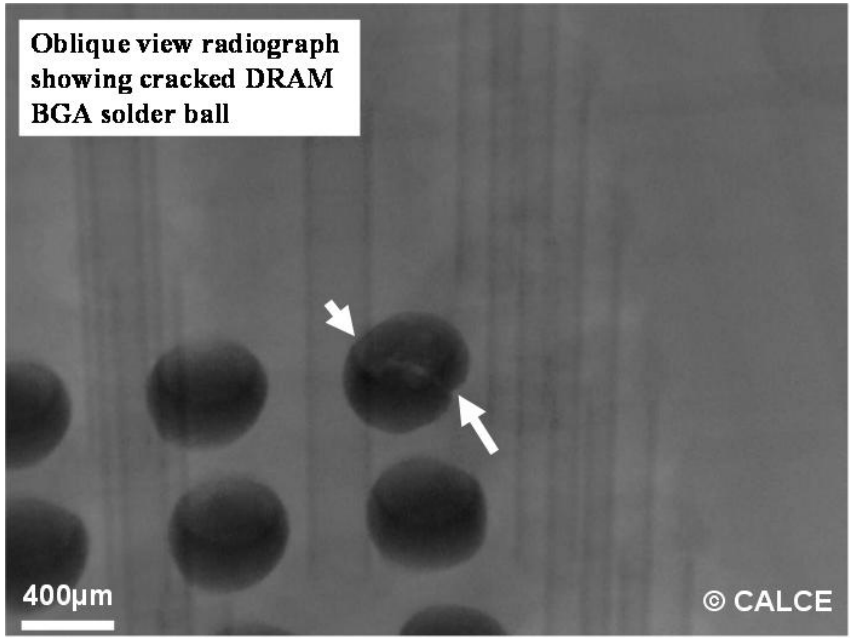
October 15-16, 2025

The reliability of electronic products and systems is increasingly critical for autonomous vehicles and vehicle safety systems. The reliability science symposium will present risk assessment, management, and mitigation techniques for heterogeneous integration, additive manufacturing, electrical contacts, life models, prognostics, battery failure mechanisms and life prediction.

Short-Course on Failure Analysis of Electronics

at University of Maryland
College Park, MD, USA
November 18-21, 2025

1. Failure analysis techniques
2. Failure mechanisms of electronic products
3. Physics-of-failure and root cause analysis
4. Hands-on laboratory sessions



Course fee: $3000 ($2500 for CALCE Members)

For more information, please contact:

Michael Osterman: +1 (301) 405 3498, osterman@umd.edu

calce

USPAE DoD Lead-Free Solder Performance and Reliability Assurance Project

AUBURN UNIVERSITY

PURDUE UNIVERSITY

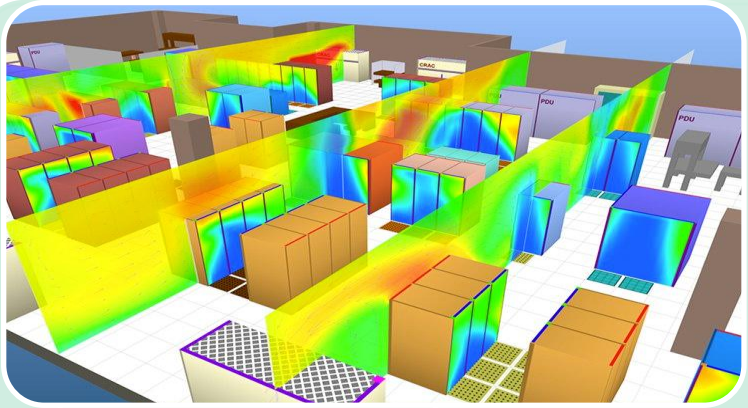
UNIVERSITY OF MARYLAND

- **Objective:** Provide the technical basis to compare and qualify solder alloys for select defense mission applications.
- **Funding:** 5 Year Effort, 2021-2026
- **Output:**
  - Solder Performance Specification
  - Solder Users Guide
- **Contact:** Michael Osterman (osterman@umd.edu) for more information

MOSTCOOL Software Capability Overview

DEAR0001755

Open source software providing seamless multi-physics simulation of data center scale thermal profiles, energy usage, CO2 footprint, reliability, availability, and cost through a user-friendly GUI.



- Will include a base library of common cooling components
- Will allow modeled data center to be placed in any climate zone
- Will allow user to specify average/hourly climate conditions
- Common system model used for energy, reliability and cost analysis
- Users build custom component modules to interface with system model
- Estimates operational CO2 emissions using national average or local carbon emission factors
- **Release 1.0 is available to COOLERCHIPS performers**

Thermal Modeling

- **Calculate rack and module temperature to within +/- 5°C**
- High fidelity modeling tools used to capture complex physics in the novel single-/two-phase cold plates developed by Topic A & B teams
- Reduced order modeling tools to model server & rack level cooling.

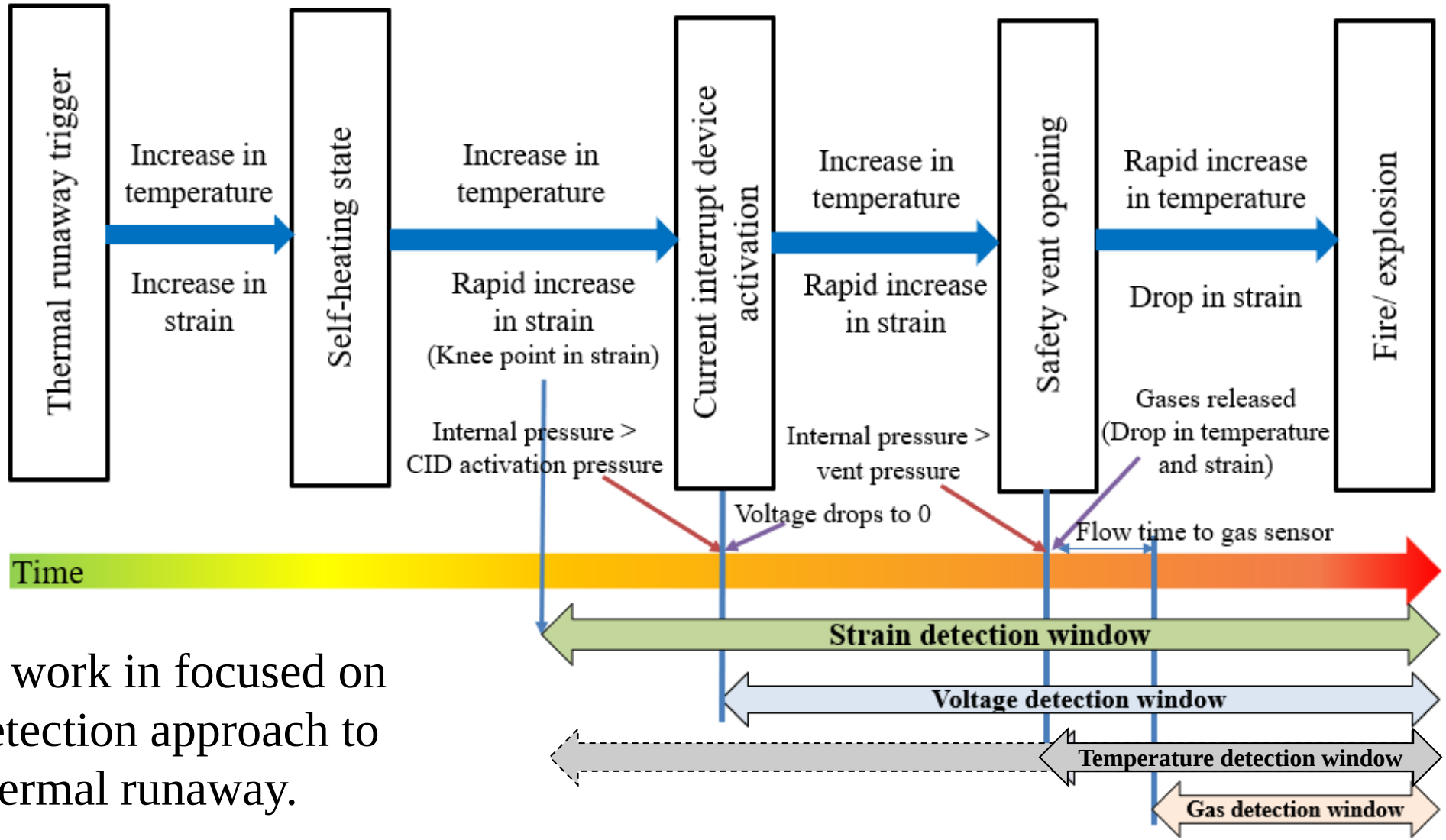
Availability Modeling

- **Predict availability to within < 1%**
- Availability determined using reliability block diagrams, Markov chain analysis, and Fault Tree Analysis.
- Based on PoF models for degradation of electronic and cooling systems requiring test data inputs from performers.
- FMEA score for component interactions

Cost Modeling

- **Path to calculate IRR and number of years to payback.**
- Will require data on cost per part, operational energy cost projection, inflation assumptions.
- Estimate both CAPEX and OPEX and allow tradeoffs such as costs of lower performance vs. costs of replacement/repair.

Preventing Thermal Runaway in Lithium-ion Batteries



CALCE work in focused on strain detection approach to avoid thermal runaway.

STEAM PIPE 23 POWER-UP MCP Project

CALCE is supporting Northup Grumman in the development of advanced multiple chip packages under the US DoD STEAM PIPE Project. Under this project, CALCE is performing life assessment modeling and reliability tests.

Northrup Grumman

Samuel Massa

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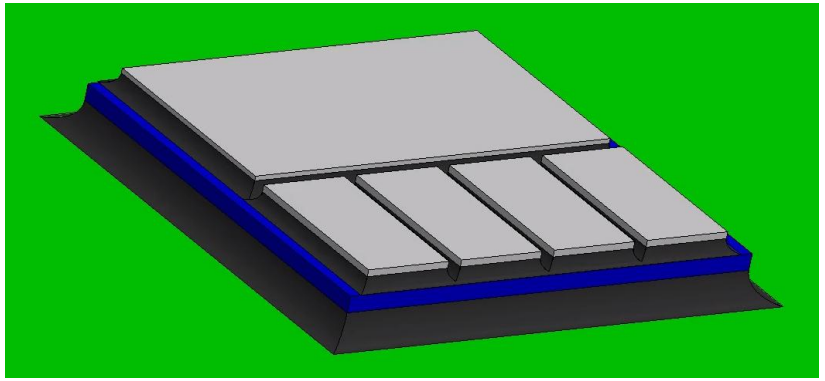
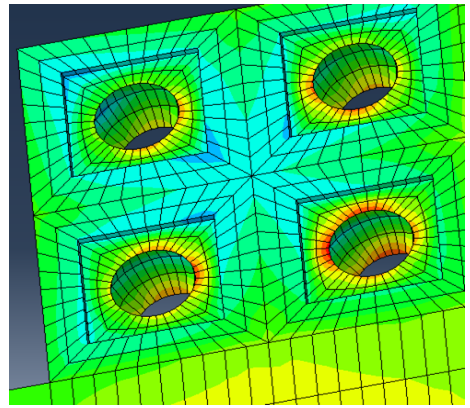
UMD CALCE

Abhijit Dasgupta

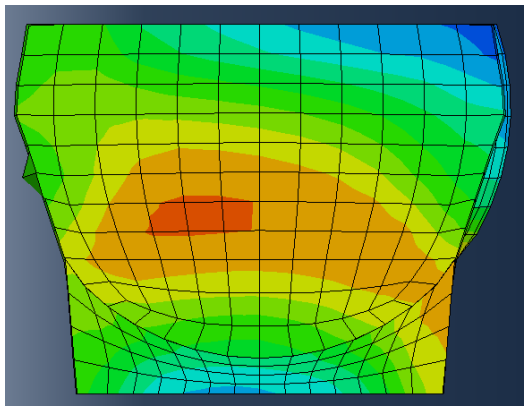
Dasgupta@umd.edu

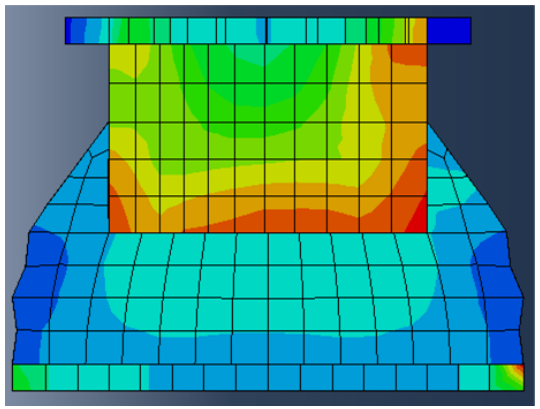


Example module



Example Undefill Stress Field





Example interconnect stress fields

Flexnode Cooling System Reliability Evaluation

- An ARPA-E project with UMD seeks to build a low environmental footprint, flexibility in installation and operation, and a relocatable cooling system. These goals can be compromised if the cooling system necessary to provide the appropriate environment is not reliable.
- This project will analyze the reliability of the proposed system concurrently with the development of the project and provide the necessary conceptual design alternatives for ensuring practical designs that account for potential failure sites, causes, modes, and mechanisms.
- CALCE faculty Dr. Diganta Das is the Principal Investigator for this project, and Prof. Michael Ohadi is leading the overall effort.

Air Force Research Laboratory STTR on Side-Channel Based Methods for Detection of Counterfeit Microelectronics

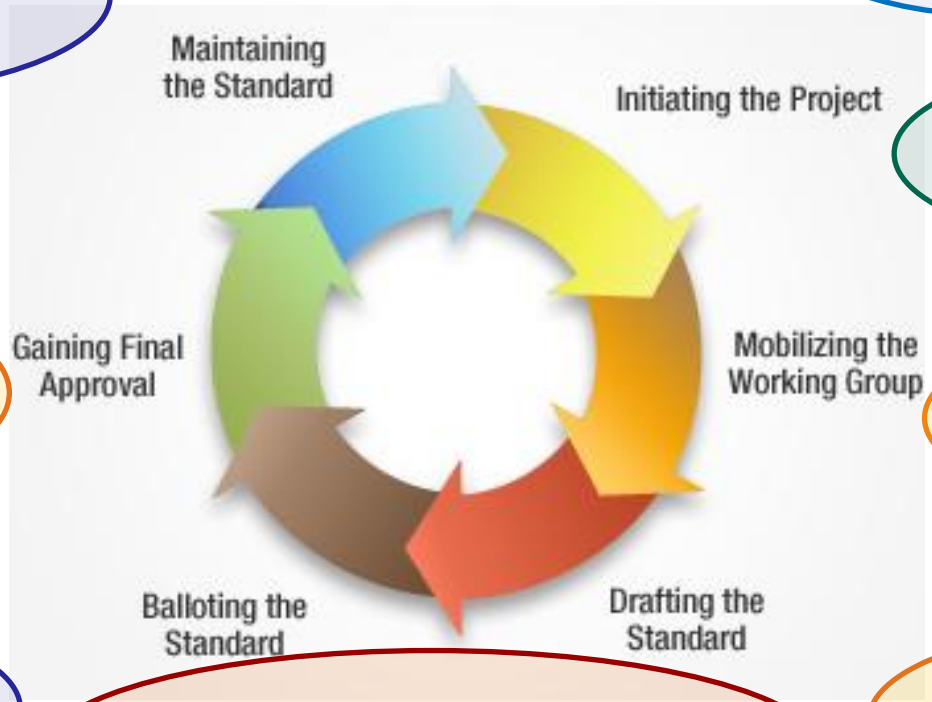
- **Objective:** Analysis and improvement of commerial side-channel platform for counterfeit detection.
- **Funding:** 2 Year Program, 2024-2026
- **Output:**
  - Commercial platform with improved accuracy
  - Calibration procedures for side-channel methods
- **Contact:** Michael Azarian (mazarian@umd.edu) or Diganta Das (diganta@umd.edu)

CALCE Standards Development and Leadership

IEEE 1413: Reliability Predictions

IEEE 1856: PHM

IPC9701 (2020) SMT Solder Attachments



IEEE 1332: Reliability Program

MIL 537: Acquisition and Sustainment of Soldered Equipment

IEEE 1413.1: Guide for Reliability Predictions

GEIA-STD-0005-2: Tin Whiskers

SAE AS6171: Counterfeit Electronic Parts Test Methods

IEEE 1624: Reliability Capability

Picture Source: IEEE Standards Association

CALCE Consortium Members 2025

- Dell
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- General Electric[1]
- Honeywell[2]
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- Google[e]
- Keysight
- Microsoft
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- NXP
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- Stryker

Superscripts: e – Enterprise, 1- 1 site, 2- 2 sites

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Projects	Next Year Proposals (2026) Current Projects (2025) Last Year Projects (2024)
Consortium Meetings	**Spring 2025** **Fall 2024**
Articles	Index
Webinars	Index
Software	calceSARA
Webbooks	Webbook Links

Access to CALCE Publications
https://calce.umd.edu/published-articles-and-book-chapters

Published in 2024

Effect of Isothermal Aging on Anisotropic Creep Properties of SAC305 Si Crystals, Aniket Bharamgonda, Johnathan Martin, Yongrae Jang, Abhij Dasgupta, Torsten Hauck, and Yaxiong Chen, 2024 23rd IEEE Intersocie Conference on Thermal and Thermomechanical Phenomena in Electro (ITherm), Aurora, CO, USA, 2024, pp. 1-6, DOI: doi.org/10.1109/ITherm55375.2024.10709443.

Quantile-based Long Short Term Memory Remaining Useful Life Predic Metal-Oxide-Semiconductor Field-Effect Transistor, Yonatan Saadon, N Auslander, and F. Patrick McCluskey, 2024 23rd IEEE Intersociety Confer Thermal and Thermomechanical Phenomena in Electronic Systems (IT Aurora, CO, USA, 2024, pp. 1-7, DOI: 10.1109/ITherm55375.2024.107095

A Novel Technique for Multiple Failure Modes Classification Based on D Algorithm, John Taco, Pradeep Kundu, and Jay Lee, Journal of Intellige Manufacturing, Volume 35 Issue 7 Page:3115-3129, DOI: doi.org/10.100 023-02185-2.

2024 23rd IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), Aurora, CO, USA, 2024, pp. 1-7, DOI: 10.1109/ITherm55375.2024.10709525

Quantile-based Long Short Term Memory Remaining Useful Life Prediction of Metal-Oxide-Semiconductor Field-Effect Transistor

Yonatan Saadon[a], Noam Auslander[b], and F. Patrick McCluskey[a]
[a] CALCE/Department of Mechanical Engineering, University of Maryland, College Park, MD, USA
[b] The Wistar Institute, Philadelphia PA, USA

For more information about this article and related research, please contact Prof. Patrick McCluskey.

Abstract:

Accurate prediction of the remaining useful life (RUL) of a degrading component is crucial to prognostics and health management for electronic systems, to monitor conditions and avoid reaching failure while minimizing downtime. However, the shortage of sufficiently large run-to-failure datasets is a serious bottleneck impeding the performance of data-driven approaches, and in particular, those involving neural network architectures. Here, we develop a new data-driven prognostic method to predict the RUL using an ensemble of quantile-based Long Short-Term Memory (LSTM) neural networks, which represents the RUL prediction task to a set of simpler, binary classification problems that are amenable for prediction with LSTMs, even with limited data. We demonstrate that this approach obtains improved RUL estimation accuracy for power MOSFETs, especially with a small training dataset that is characterized by a wide range of the RUL.

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CALCE Webinars

https://calce.umd.edu/webinars

Temperature-Humidity-Bias and Temperature Cycling Reliability of Printed Electronics - 4/17/2025

Thermal Cycle Reliability of Low Temperature Solders - 5/15/2025

Webinar archive

Electronics continue to evolve on the leading edge of technology development. As such, engineers who develop or use electronic systems technologies must be able to synthesize interdisciplinary knowledge from many diverse sources: electrical, mechanical, thermal, materials, manufacturing, and business. In addition, they must be able to effectively communicate (verbally and in writing) and be adept at working on teams.

Rapid advances in electronic products and systems require special efforts to educate the techn workforce. These special efforts include using systematic just-in-time transfer of state-of-the-art knowledge derived from the latest research results.

TOP

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CALCE EPS Consortium Research

Below you will find the achive of past CALCE EPS
questions regarding individual project to list proje
contact Michael Osterman, Director CALCE EPS

- FY25 Research
- FY24 Research
- FY23 Research
- FY22 Research
- FY21 Research
- FY20 Research

ID	Title
C25-03	**Effect of Aging and Recrystallization on Performance of Oligocrystalline SAC Solder Joints**
C25-06	**Physics of Failure Based Electronic Product Design Review**
C25-07	**Reliability of Lead-free High-Performance Solder Interconnects**
C25-08	**Reliability of Low Temperature Solder Interconnects**
C25-11	**Guidelines for Storage of Printed Board Assemblies and Electronic Equipment**
C25-19	**Validation of Selection Criteria for Use of Multilayer Ceramic Capacitors MLCCs with Ripple Current**
C25-20	**Rapid Assessment of Electronic Products Using Side-Channel Power Modulation Analysis**
C25-22	**Fretting of Electrical Contacts Finished with Electroless Gold**
C25-26	**Coating Durability in Electronic Products**

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CALCE EPS Consortium Research

Below you will find the achive of past CALCE EPSC presentations organized by year. Please direct quest individual project to list project investigator. For gene contact Michael Osterman, Director CALCE EPSC.

FY25 Research	Spring
FY24 Research	Spring
FY23 Research	Spring
FY22 Research	Spring
FY21 Research	Spring

March 26, 2025 (Wednesday)

View Presentations and Provide Feedback - Session 1

9:00 am - Opening Presentations I CALCE Overview

9:30 am - Session I

- Validation of Selection Criteria for Use of Multilayer Ceramic Capacitors MLCCs with Ripple Current (Members' Only)
- Fretting of Electrical Contacts Finished with Electroless Gold (Members' Only)
- Rapid Assessment of Electronic Products Using Side-Channel Power Modulation Analysis (Members' Only)

11:00 am - Session II

View Presentations and Provide Feedback - Session 2

- Physics of Failure Based Electronic Product Design Review (Members' Only)
- Guidelines for Storage of Printed Board Assemblies and Electronic Equipment (Members' Only)
- Simulation of Die Level Failure Mechanisms (Members' Only)
- Adaptive Prognostics and Health Management of Digital Circuits (Members' Only)

EPS Consortium Research Projects: 2025

C25-19 Validation of Selection Criteria for Use of Multilayer Ceramic Capacitors (MLCCs) with Ripple Current

C25-20 Rapid Assessment of Electronic Products Using Side-Channel Power Modulation Analysis

C25-22 Fretting of Electrical Contacts Finished with Electroless Gold

C25-11 Guidelines for Storage of Printed Board Assemblies and Electronic Equipment

C25-03 Effect of Aging and Recrystallization on Performance of Oligocrystalline SAC Solder Joints

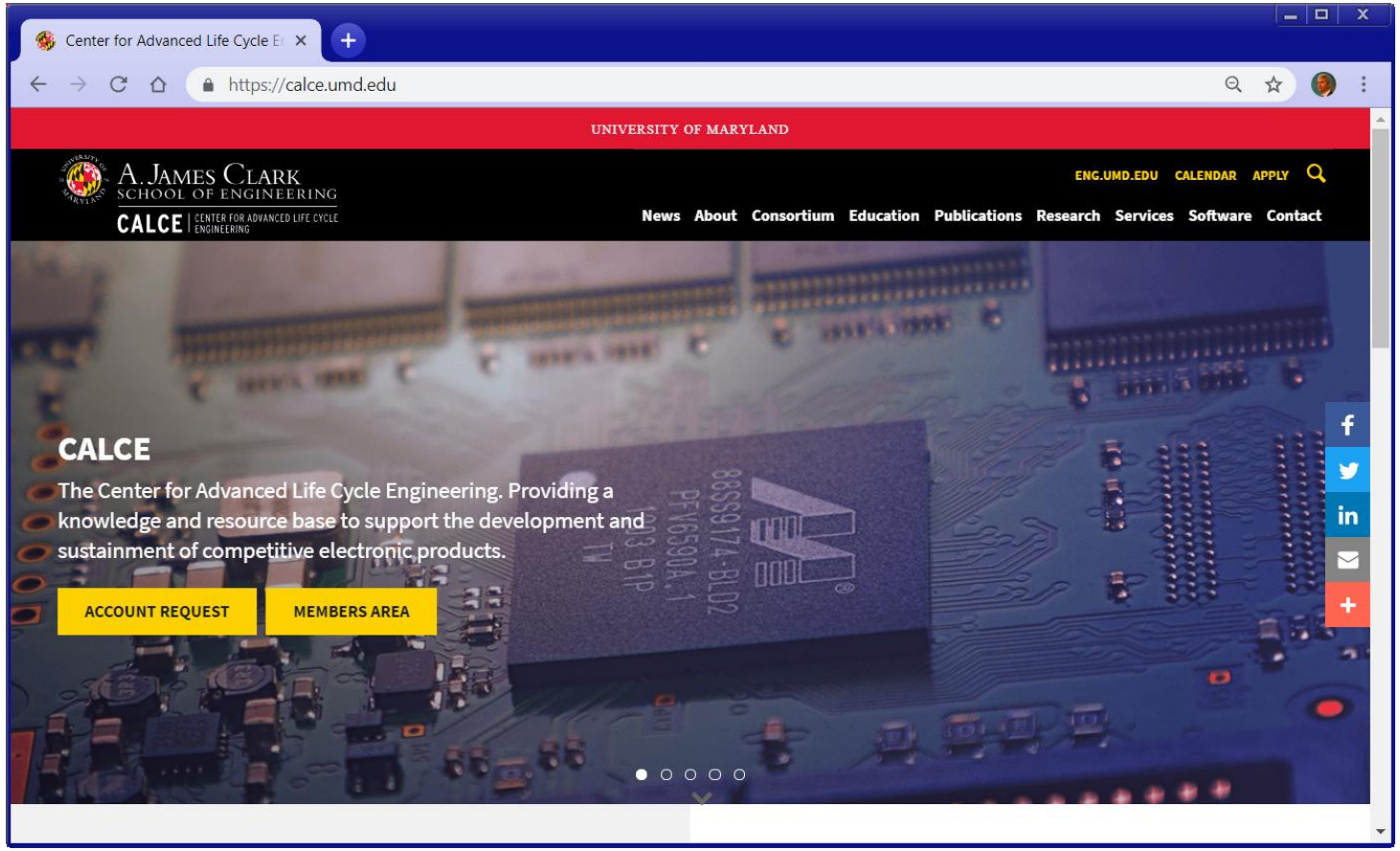
C25-26 Coating Durability in Electronic Products

C25-06 Physics of Failure Based Electronic Product Design Review

C25-07 Reliability of Lead-free High-Performance Solder Interconnects

C25-08 Reliability of Low Temperature Solder Interconnects

Questions



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