Welcome to the CALCE Reliability Science for Electronics Symposium

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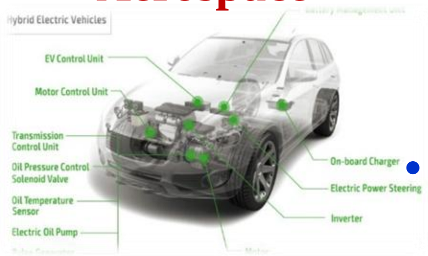
osterman@umd.edu

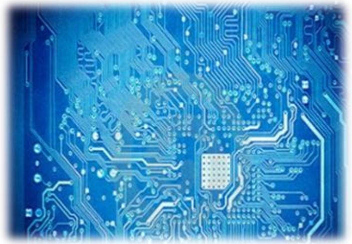
CALCE Activities

Reliable, Safe, Secure Microelectronic Systems

Military & Aerospace



Automotive

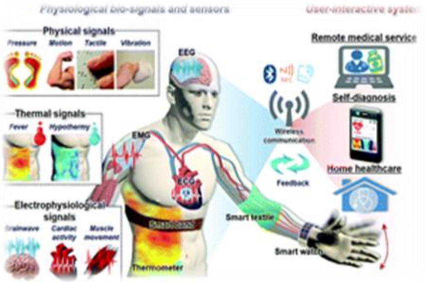


Computing and Data Systems

Servers and HPCs

- **Research Consortia**
  - Shared basic research projects, software access, seminars, consulting, discounted test services, and 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
- **Education**
  - Degree and certificate programs, on-site customized professional development courses, web-based workshops, internships, community college outreach, and regional consortia
- **Standards and Roadmaps Development**
  - Standards and roadmap development through societies and organizations such as IEEE, ASME, SEMI, IPC, US Military, and SAE

Industrial Systems



Healthcare Systems

Communications

Energy Systems

CALCE Electronics Life Cycle Focus

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
- Security assessment
- Life assessment

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

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

End-of-Life
- Recycle
- Reuse
- Repurpose
- Disposal

Disruption management
(Supply chain risk, Allocation, Security)

Supply-chain and life cycle cost management

Compromise management
(Obsolescence, Counterfeit)

Test and Measurement Laboratories

CALCE has a sophisticated test and failure analysis laboratory to support research and industry needs.

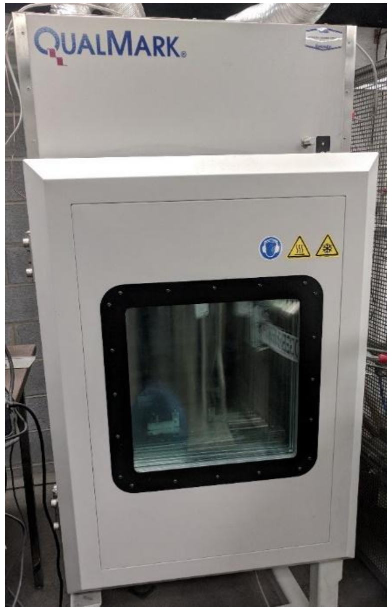
- **Materials characterization (including Micro/Nano-Scale)**
- **Accelerated Environmental Testing**
- **Failure Analysis**
- **Electrical Characterization and Diagnostics**
- **Modeling and Simulation**
- **Thermal Management**

Scanning Acous

Scanning Electr
and Energy
Spectroscopy

Analyzer

Analyzer



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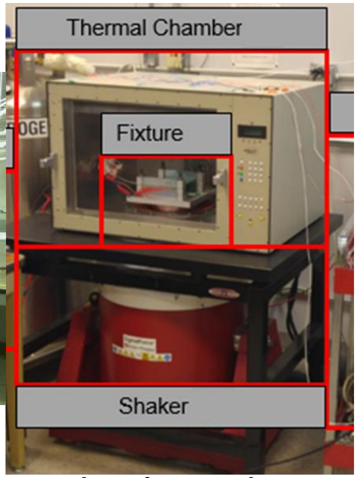


ombined Vib and
Thermal Cycling

Current CALCE Consortium Members 2025

- Dell
- Duksan Hi-Metal
- General Electric[1]
- Honeywell
- L3Harris [e]
- Lockheed
- Google [e]
- Keysight
- Microsoft
- Medtronic
- NXP
- Rolls Royce
- Sandia National Labs
- Schlumberger Oil Drilling Services
- Stryker
- Woodward

e – Enterprise

Consortium Membership Benefits

https://calce.umd.edu/join-calce-eps-consortium

- Input into annual consortium research projects and roadmaps
- Shared access to results from over $120 million in previous research
  - Research projects and proceedings
  - Publications
  - **Webinars**
- Advanced access to latest **CALCE Simulation Assisted Reliability Assessment software** and software support
- Technical exchange with other members and leveraging your research dollars
- Interaction with CALCE graduate students and potential internships
- Technical consulting with CALCE Research Staff and insight into non-consortium research
- Discount on CALCE short-courses, CALCE fee-for-services and CALCE sponsored events

CALCE Webinars from 2025

https://calce.umd.edu/webinars

Fretting Wear in Electrical Contacts: Can Electroless Gold Replace Electroplated Finishes? - 9/9/2025

Drop Durability of Additive and Conventional Electronic Interconnects at Elevated Temperature and under Multiaxial Loading - 8/14/2025

Die-Level Failure Assessment Process Based on Part Technology - 7/10/2025

Quantitative Prediction of Warpage after Molding Processes: Is It a Myth? - 6/5/2025

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

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

Digital Twin-Driven Prognostics and Health Management for Digital Circuits - 3/6/2025

Are We Getting the Necessary Thermal Information in the Semiconductor Part Datasheets? - 2/13/2025

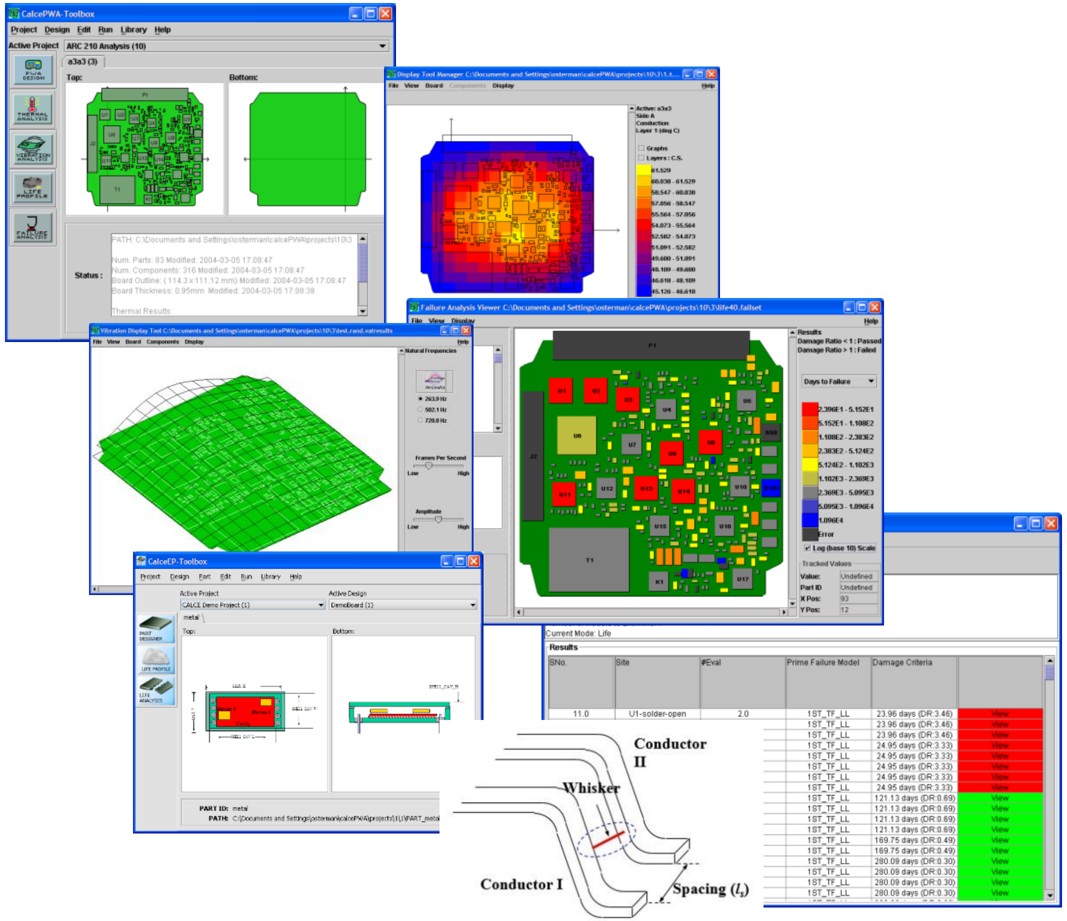
Swelling in Lithium-Ion Batteries: Causes, Characterization, and Thermal Runaway Detection - 1/23/2025

A new set are being planned for 2026

CALCE Simulation Assisted Reliability Assessment Software

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

Downloads/Activation 2025: 132



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 new features and data sets.

Training is available.

calceSARA Updates Release 8.6.7

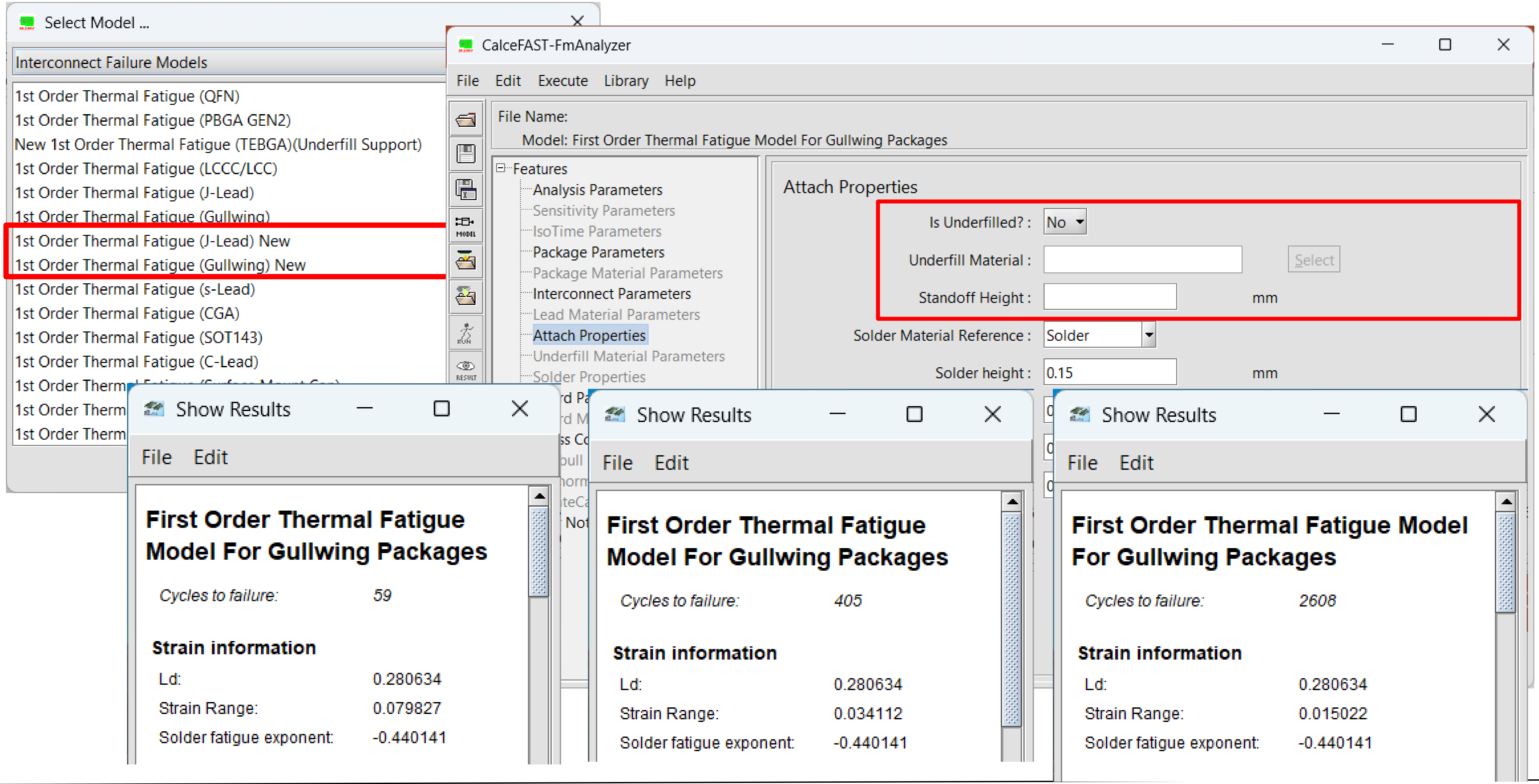
- Updates report template for multiple environment evaluation for CALCE FAST 1st order fatigue models.

- Added underfill consideration for new J-lead and new gullwing 1st order thermal fatigue models implemented in calceFAST.

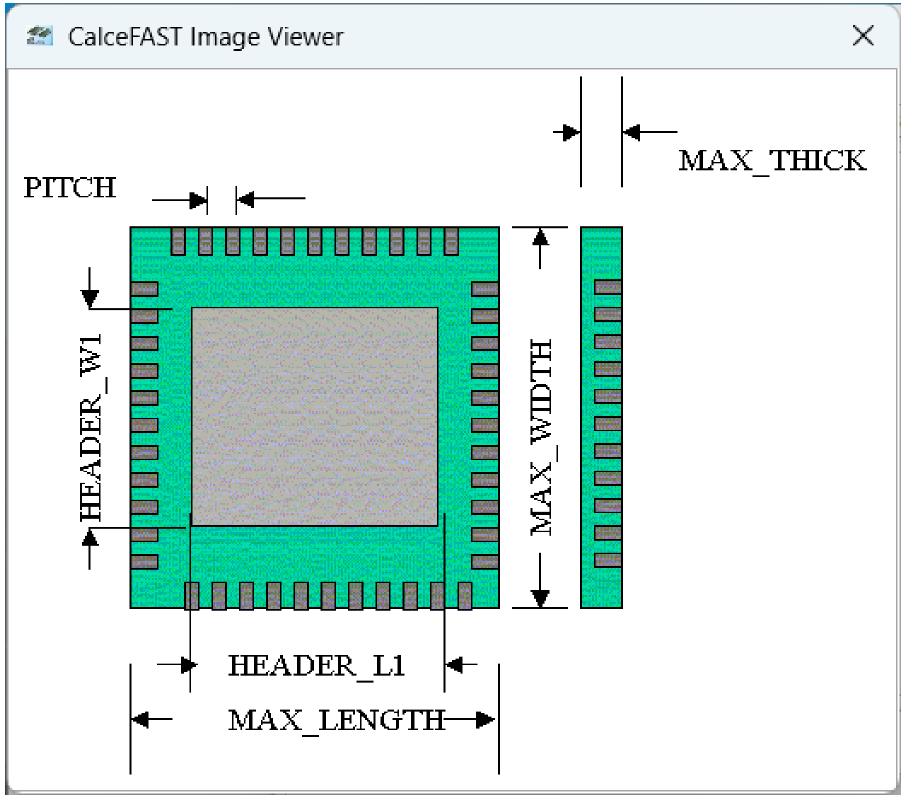
- Modified the dynamic input manager in the life cycle profiler.

- Updated the QFN for part parameter definitions.

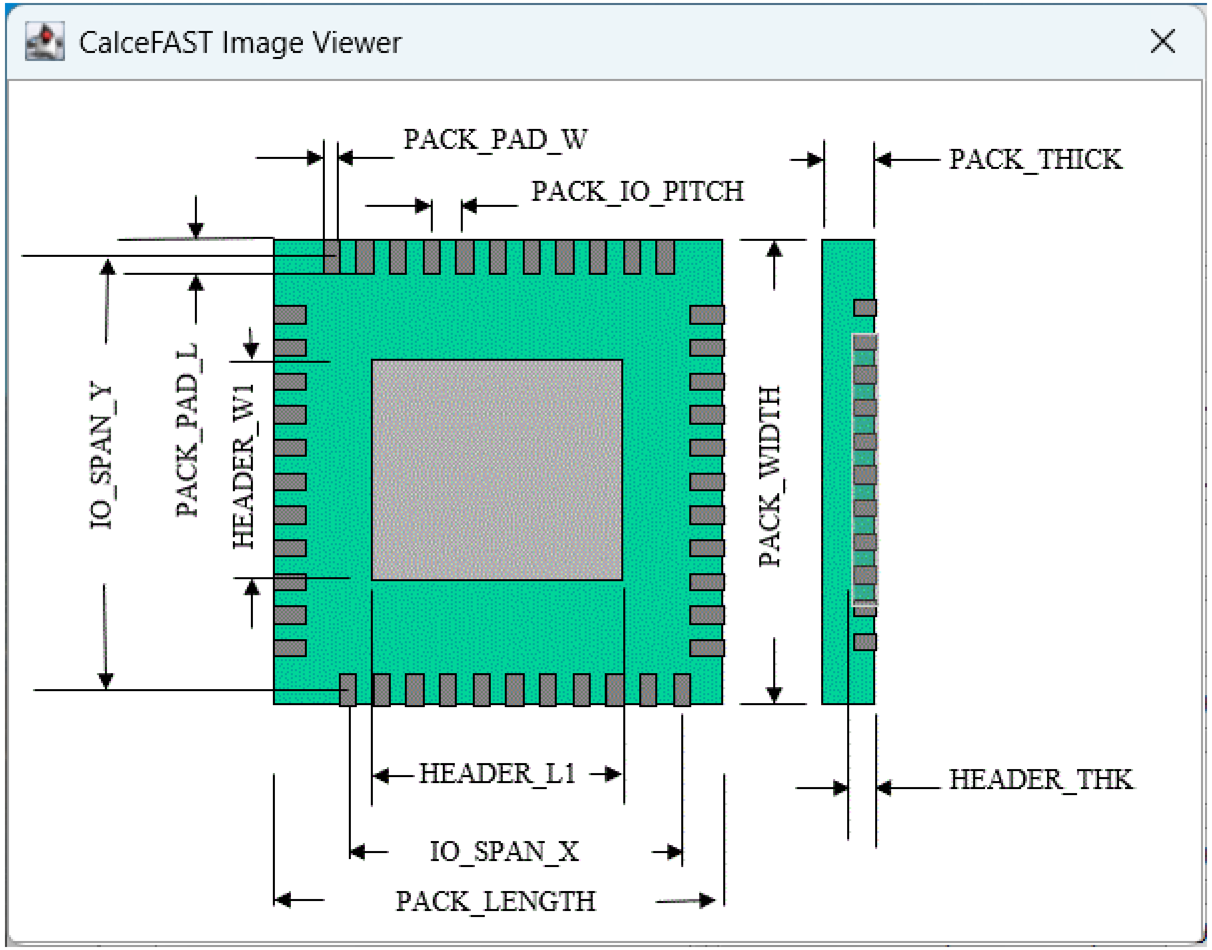
Underfill for Leaded Packages in CalceFAST



QFN Figure for calceFAST

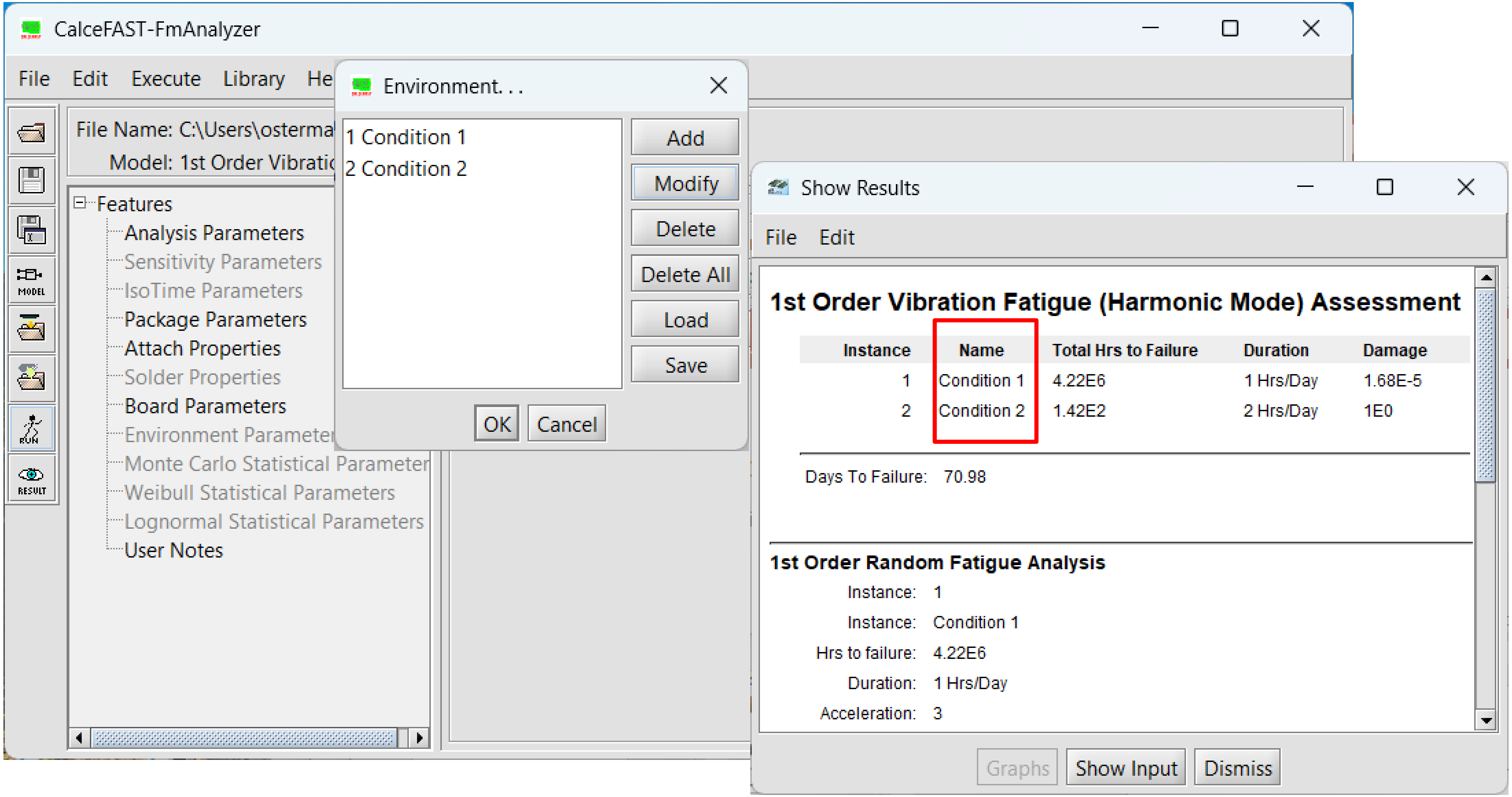


calceFAST Release 8.6.5



calceFAST Release 8.6.7

Labeling of Environmental Conditions in Results - CalceFAST



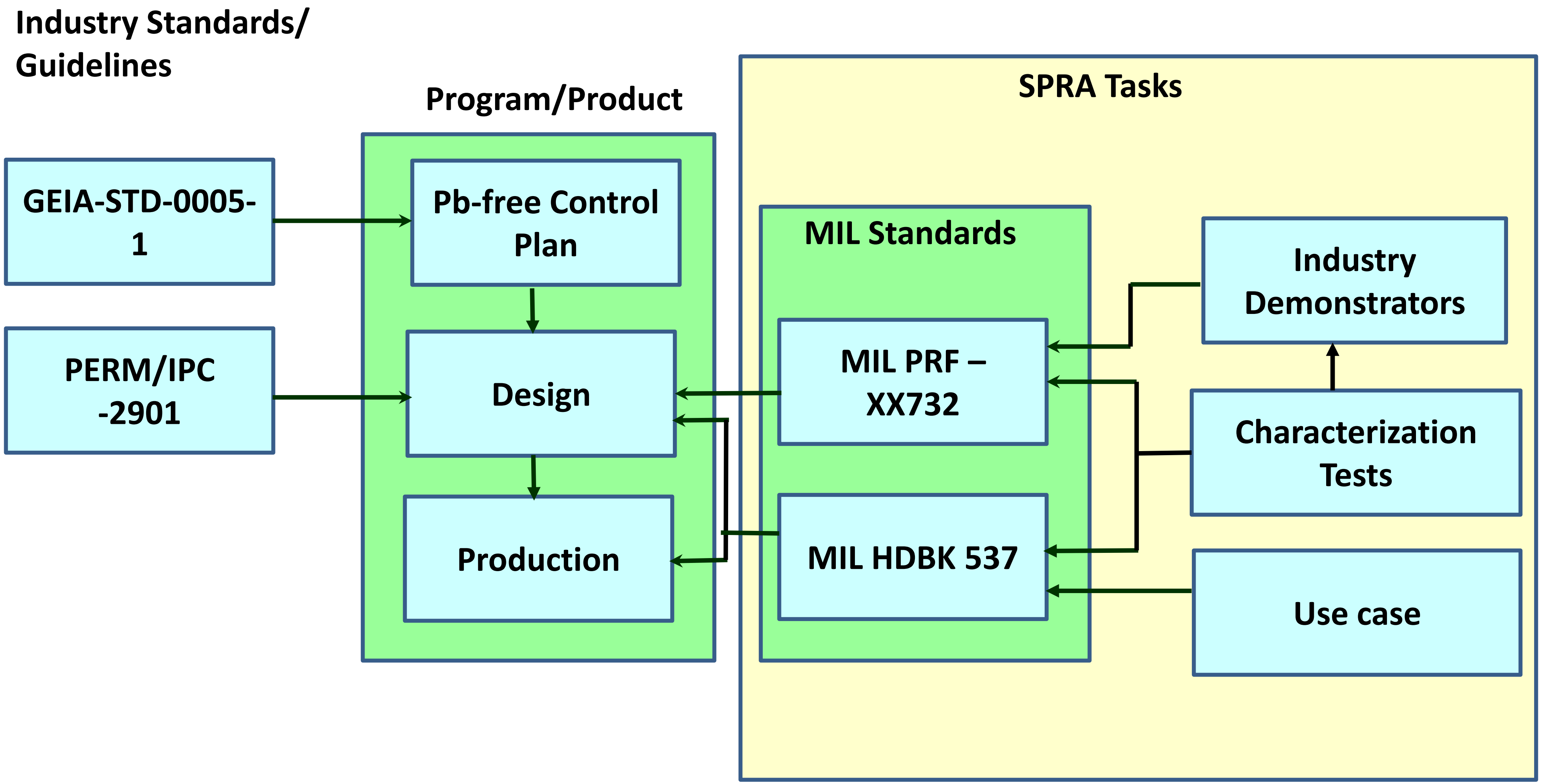
Current Contracts

- Multi-Objective Simulation Tool for Cooling Optimization and Operational Longevity – ARPA-E Contract – CALCE Lead: McCluskey -Team: NREL, LBNL, Univ. of Arkansas, Trane
- Cooling System Reliability Evaluation – Flexnode with ARPA-E Contract - CALCE Lead: D. Das – Team: Flexnode
- Advanced Packaging Reliability in Heterogeneous Integration, Government of Israel, Lead: D. Das, Team: Defense Security Cooperation Agency
- Side-Channel Based Methods for Detection of Counterfeit Microelectronics - Air Force Research Laboratory STTR – CALCE Lead: D. Das and Azarian - Team Chiplytics
- Multichip Module Interconnect Evaluation – STEAM PIPE 23 POWER-UP – CALCE Lead: Dasgupta - Team: Northrop Grumman
- Solder Performance and Reliability Assurance – USPAE Contract - CALCE Lead: Osterman - Team: Auburn University, Purdue University, Collins, Plexas, STI Electronics
- Substrate-based Heterogeneous Integration Enabling Leadership Demonstration for the USA - NIST CHIPS NAPMP-1 – DECA/IBM, ASU/UMD(CALCE-ISR); CALCE Lead: Dasgupta
- Advanced Materials and Additive Manufacturing of Printed Electronics for Harsh Environment, FlexTech-ARL, CALCE Lead: Dasgupta
- Additively Manufactured Printed Hybrid Electronics for Extreme Shock/Drop at Elevated Temperature, ARL, CALCE Lead: Dasgupta
- Development of Three-Dimensional Hard X-Ray Photoelectric Polarimeter Assembly Using Additive Manufacturing Technology, NASA APRA, CALCE Lead: Siddhartha Das
- Reliability of Printed Hybrid Electronics under Temperature and Moisture Environments, LPS, CALCE Lead: Abhijit Dasgupta

USPAE DoD Lead-Free Solder Performance and Reliability Assurance Project

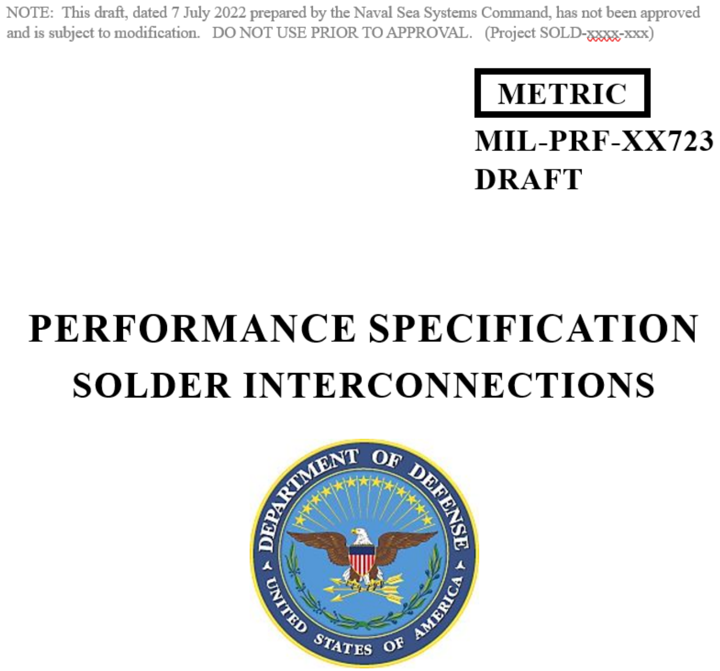
- **Objective:** Provide the technical basis to compare and qualify solder alloys for select defense mission applications.
- **Funding:** 5 Year Effort, 2021-2026
- **Output:**
  - Solder Performance Specification
  - Solder Users Guide
- **Contact:** Michael Osterman (osterman@umd.edu) for more information

Where do SPRA Work Products Fit?



Performance Specification to Data Product Specification

Update from program revision received July 3, 2025


NOTE: This draft, dated 7 July 2022 prepared by the Naval Sea Systems Command, has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL. (Project SOLD-xxxx-xxx)

METRIC

MIL-PRF-XX723

DRAFT

PERFORMANCE SPECIFICATION

SOLDER INTERCONNECTIONS

Scope:

This data product specification is used to acquire the technical data that enable program managers to make informed decisions when selecting and using specific solders in soldered defense electronic products. …This specification pertains to baseline solder technical data only and does not qualify solder or replace any qualification testing of defense electronic products. …

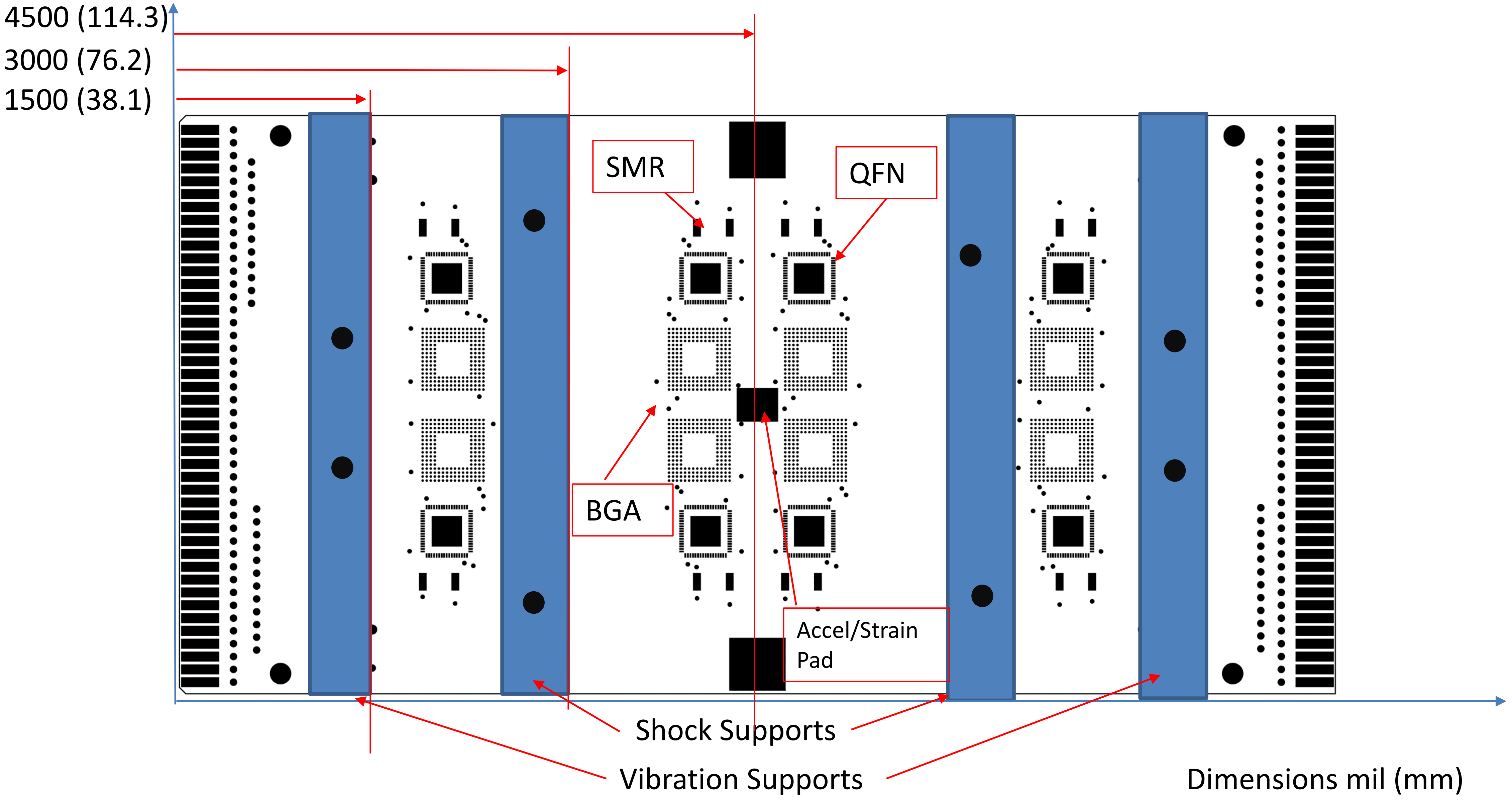
Environmental Test Conditions (Requirements 3.3.x and Verifications 4.5.x)

Mechanical Shock: The solder under evaluation **shall** maintain electrical continuity and physical integrity while being subjected to [30] a mechanical shock stress with an acceleration peak normal to the board surface of 1500 *g* -0 / +150 *g. 0.5 ms*

Vibration: The solder under evaluation **shall** maintain electrical continuity and physical integrity while being subjected to a sinusoidal vibration at first harmonic +-/- 10 Hz normal to the board surface at a maximum board strain of [250] µstrain for 1 hour.

Thermal Cycling: The solder under evaluation **shall** maintain electrical continuity and physical integrity while being subjected [300] thermal cycling stress of −55 to +125 ℃.

SPRA – Proposed Performance Test Vehicle



MIL-HDBK-537 A

Guidance for the Acquisition and Sustainment of Soldered Defense Electronic Products

Update from program revision received July 3, 2025

1. SCOPE

This handbook covers soldering technologies for the acquisition and sustainment of soldered defense electronic products. This handbook is for guidance only and cannot be cited as a requirement. The guidance in this handbook is a collection of best practices for soldering defense electronic products.

2. APPLICABLE DOCUMENTS
3. DEFINITIONS
4. ACQUISITION GUIDANCE
5. SUSTAINMENT GUIDANCE
6. NOTES

SPRA MIL-HDBK-537 Appendices

Appendix A Pb-free Solder Material and Processes
Appendix B Assembly Readiness
Appendix C Copper Dissolution
Appendix D Tin Whiskers
Appendix E Gold Embrittlement
Appendix F Mechanical Failure Mechanisms, Models, and Tests for Solder in Electronics
Appendix G Electromigration
Appendix H Isothermal Aging of Solder
Appendix I Use Case Development and Assessment for Solder Interconnects

SPRA - Solder Under Test

- Sn37Pb – Eutectic Tin-Lead Solder is included in the test as a baseline. The inclusion of Sn37Pb allow for comparison with exciting models and data.
- SAC305 – Major Pb-free replacement for Sn37Pb. Like Sn37Pb, the inclusion of SAC305 allow for comparison with existing models and data.
- Innolot – Third generation Pb-free alloys have shown improvements over SAC305. Specifically, the tin-silver-copper alloys that have added bismuth (Bi) and antimony (Sb) have shown superior thermal cycling performance to SAC305.

Alloy	Composition (wt. %)							Melt Range (°C)
	Sn	Ag	Cu	Bi	Sb	Pb	Other	
Sn37Pb	63.0					37.0		183
SAC305	96.5	3.0	0.5					217-221
Innolot	91.3	3.5	0.7	3.0	1.5		0.12Ni	206-218

SPRA Components Under Test

- Ball Grid Array – 192 IO perimeter array, 14 x 14 mm, 0.8 mm pitch, 0.46 mm solder spheres
- Ball Grid Array – 360 IO perimeter array, 10 x 10 mm, 0.4 mm pitch, 0.25 mm solder spheres

- QFN – 32 IO , 7 mm x 7 mm, 0.65 mm pitch, Pilot Shock Tests
- QFN – 68 IO , 10 mm x 10 mm, 0.5 mm pitch, Characterization tests

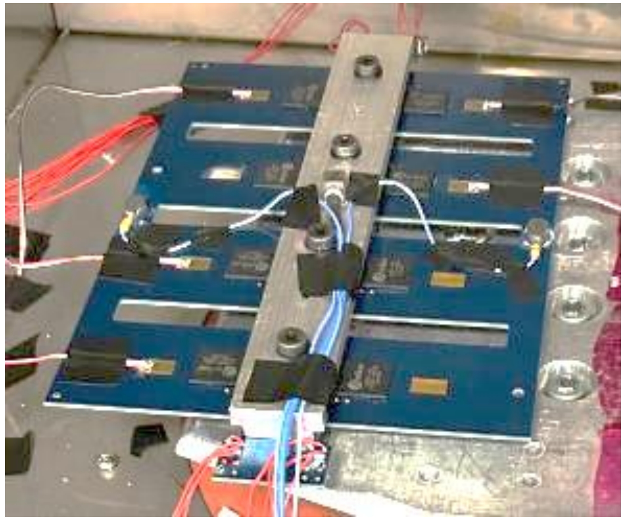
- SMR2512 – 2 IO, 6.3 mm by 1.57 mm, Characterization tests

SPRA Test Vehicles

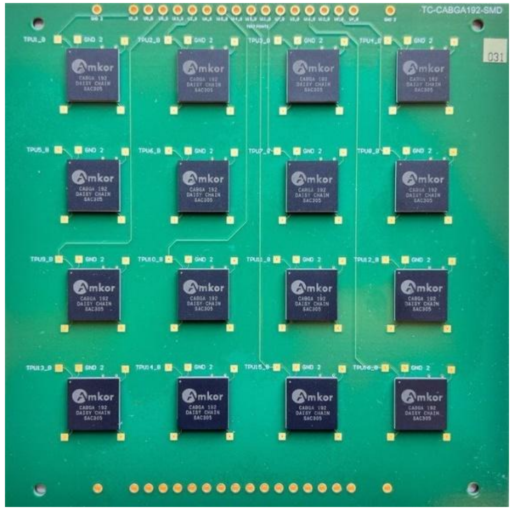
- The test vehicles are based on the test printed board assemblies being used in the SPRA tests.

Mechanical Shock

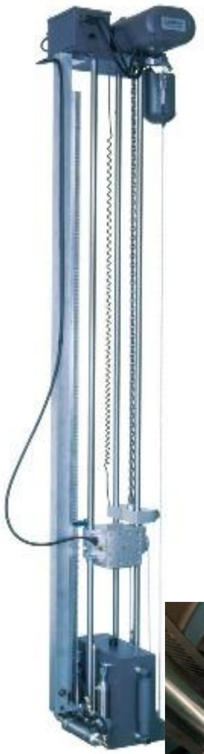
Vibration

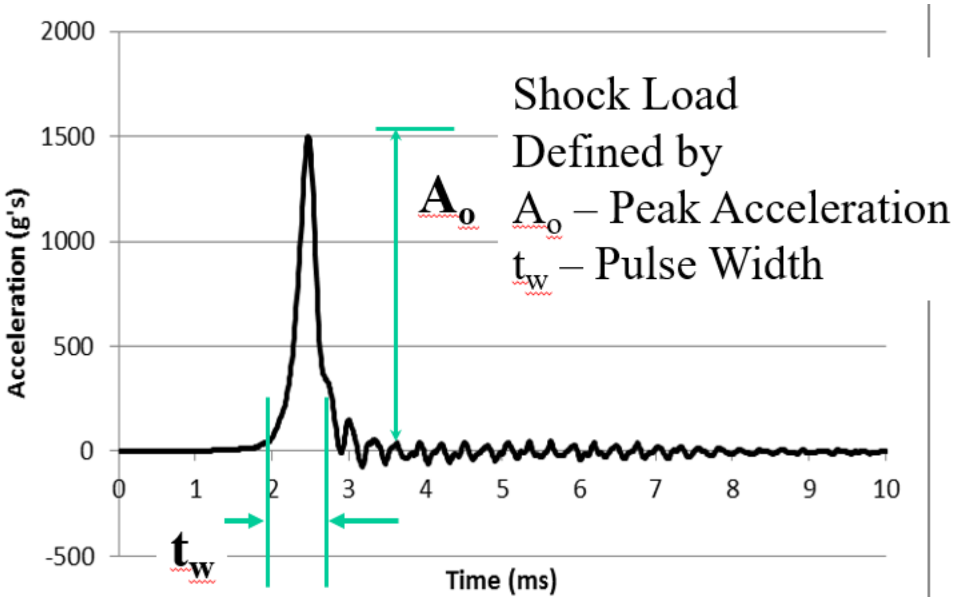


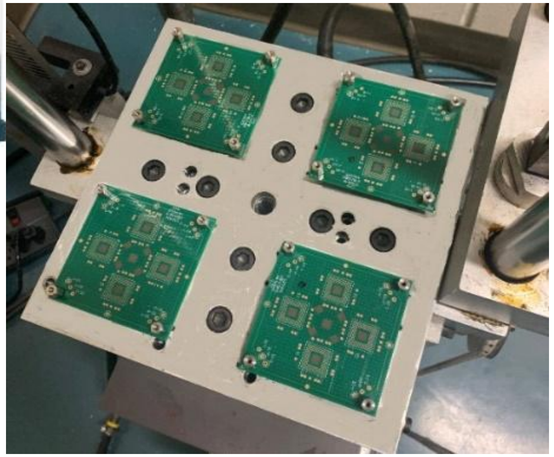
Thermal Cycling

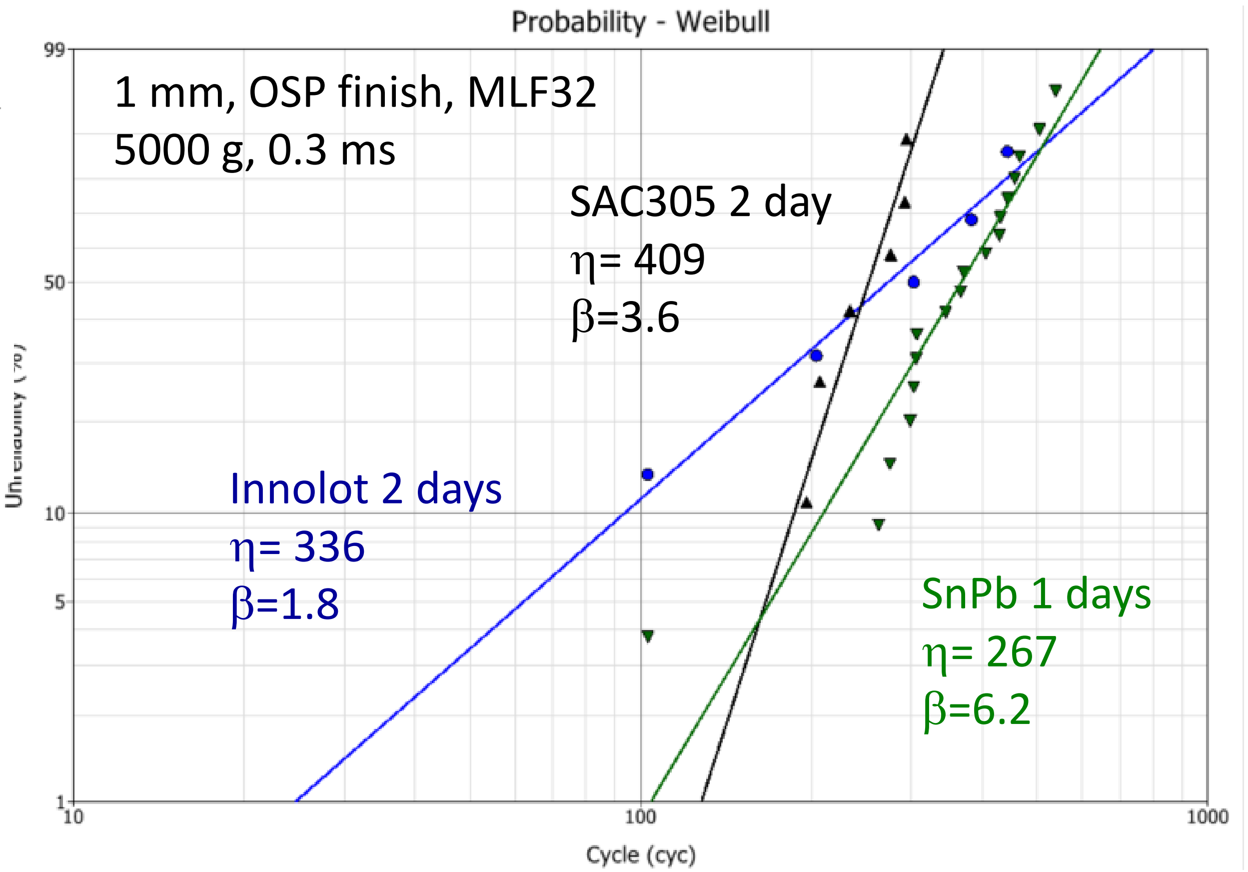


SPRA Shock Test Result



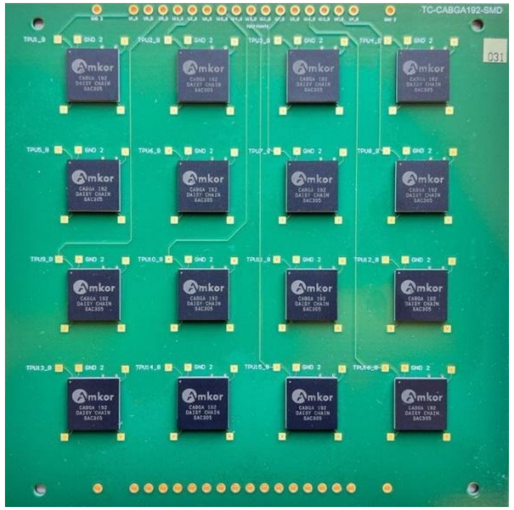


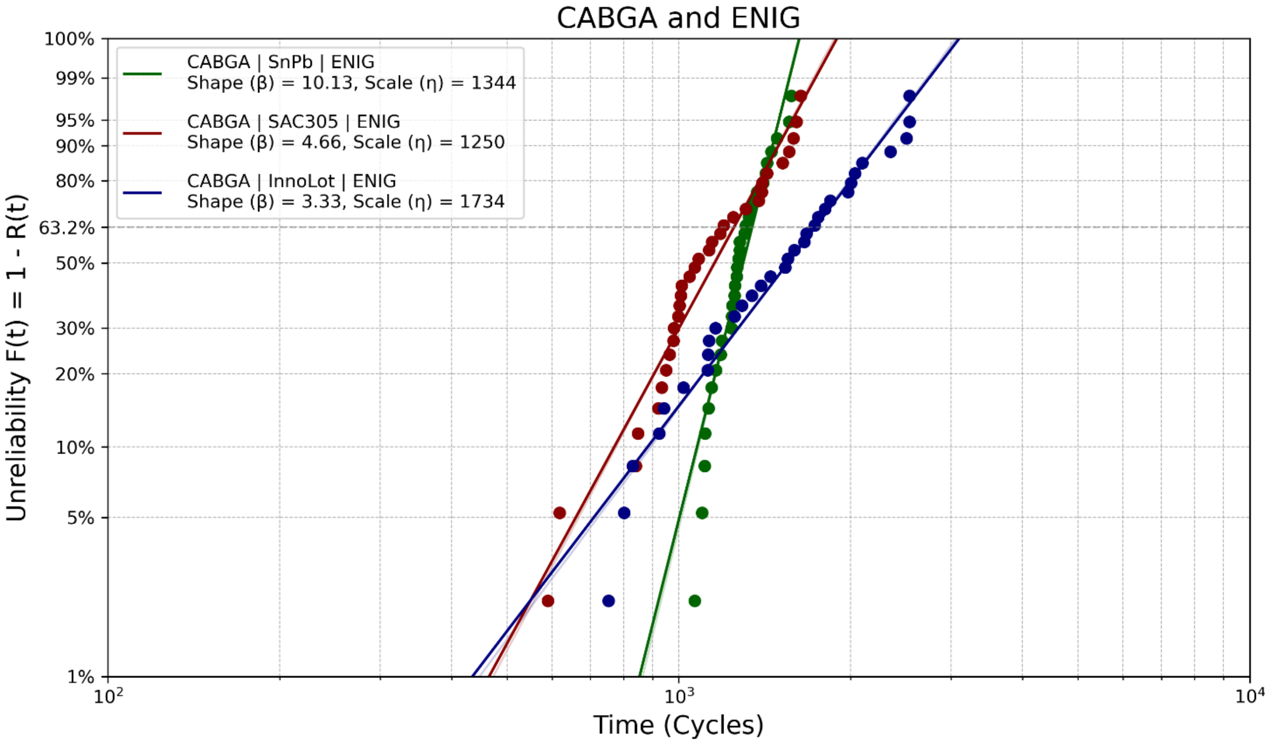




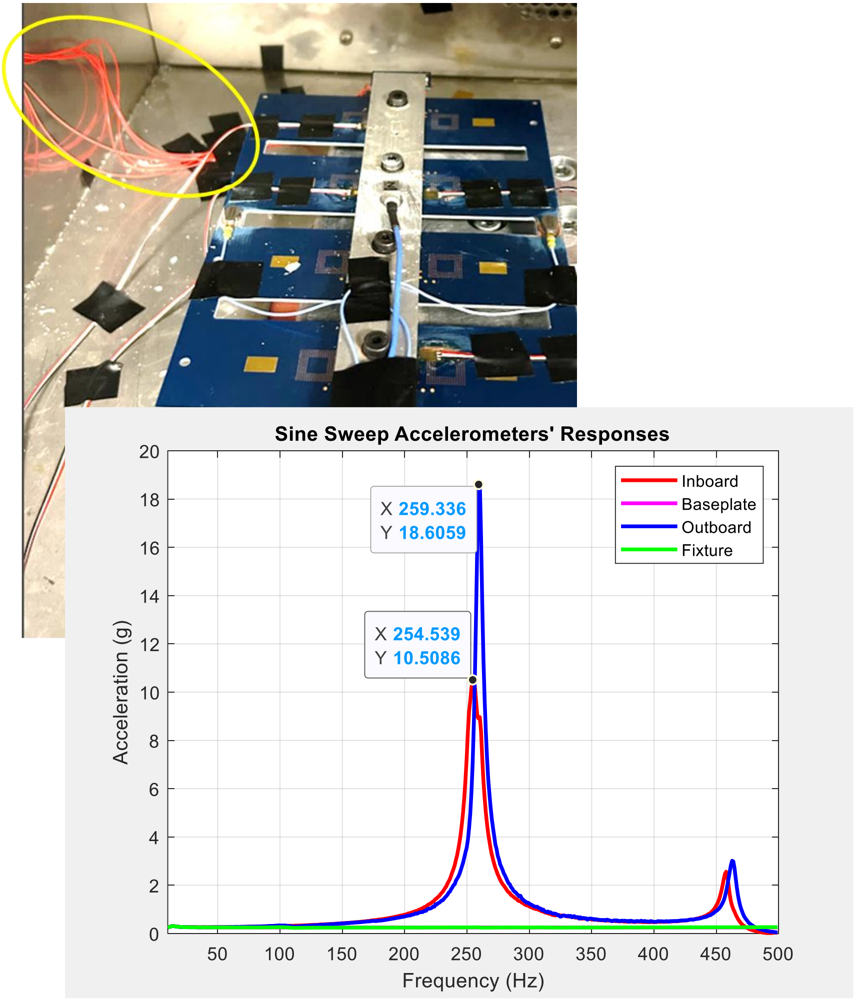
SPRA Thermal Cycling Test Result

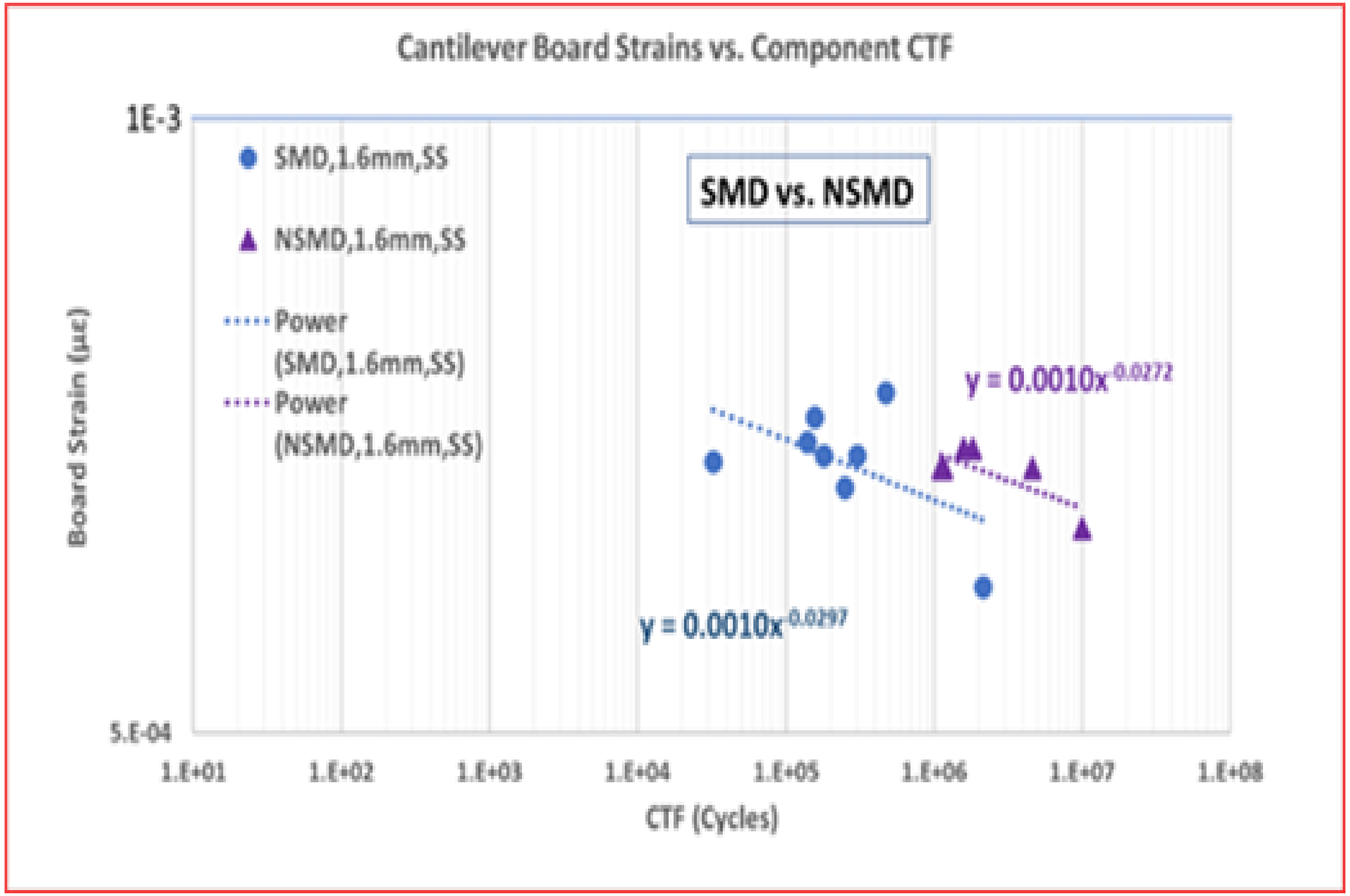
Minimum Temperature	-55 (℃)
Maximum Temperature	125 (℃)
Delta T	180 (℃)
Average Temperature	35 (℃)
Dwell Time	15 (minutes)
Ramp Rate	10 (℃/min.)
Cycle Duration	66 (minutes)





SPRA Vibration Pilot Test Result

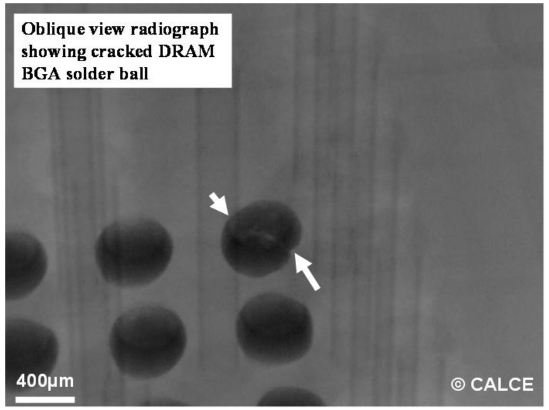




Short Course on Failure Analysis of Electronics

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

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- Unison Industries
- Universal Lighting Technologies
- Vertiv
- Waites
- Whirlpool
- X-Wave

- Consumer and mobile products
- Telecommunications and computer systems
- Energy systems (generation/storage/distribution)
- Industrial systems
- Automotive systems
- Aerospace systems
- Medical systems
- Defense systems
- Equipment manufacturers
- Government laboratories and agencies

Reliability Science for Electronics Symposium - Morning

Session 1

- Rapid Assessment of Electronic Products Using Side-Channel Power Modulation Analysis
- Fretting of Electrical Contacts Finished with Electroless Gold
- Coating Durability in Electronic Products

Session 2

- Reliability of Lead-free High-Performance Solder Interconnects
- Reliability of Low Temperature Solder Interconnects
- Effect of Aging and Recrystallization on Performance of Oligocrystalline SAC Solder Joints

Reliability Science for Electronics Symposium - Afternoon

Session 3

- Physics of Failure Based Electronic Product Design Review
- Guidelines for Storage of Printed Board Assemblies and Electronic Equipment
- Reliability Analysis of Thermal Management of an Edge Data Center
- Continued Concerns with the Use of Mil-Hdbk-217, Telcordia and FIDES

Session 4

- Validation of Selection Criteria for Use of Multilayer Ceramic Capacitors MLCCs with Ripple Current
- Adaptive Prognostics and Health Management of Digital Circuits
- UL Strain Monitoring For Battery Safety
- Critical Hole Size Causing Thermal Runaway in Lithium-ion Battery Separators