DfR Solutions
RELIABILITY DESIGNED & DELIVERED

DfR Solutions -Your Partner Throughout the Product Life Cycle

Vidyu Challa and Greg Caswell

Who is DfR Solutions?

The Industry Leader in Quality-Reliability-Durability of Electronics

Fastest Growing Companies in the Electronics Industry

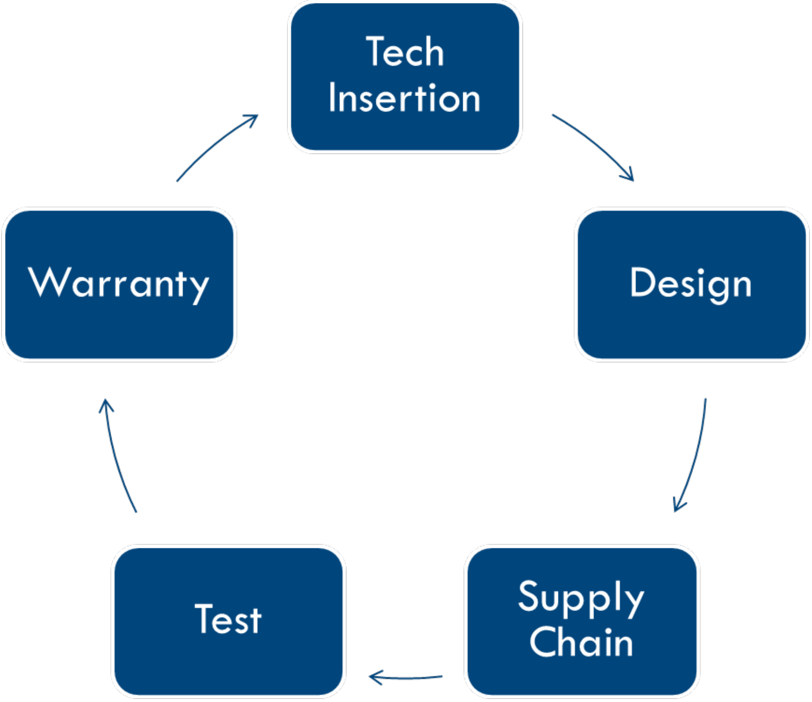
- Inc Magazine

Best Design Verification Tool

- Printed Circuit Design

2012 Global Technology Award Winner

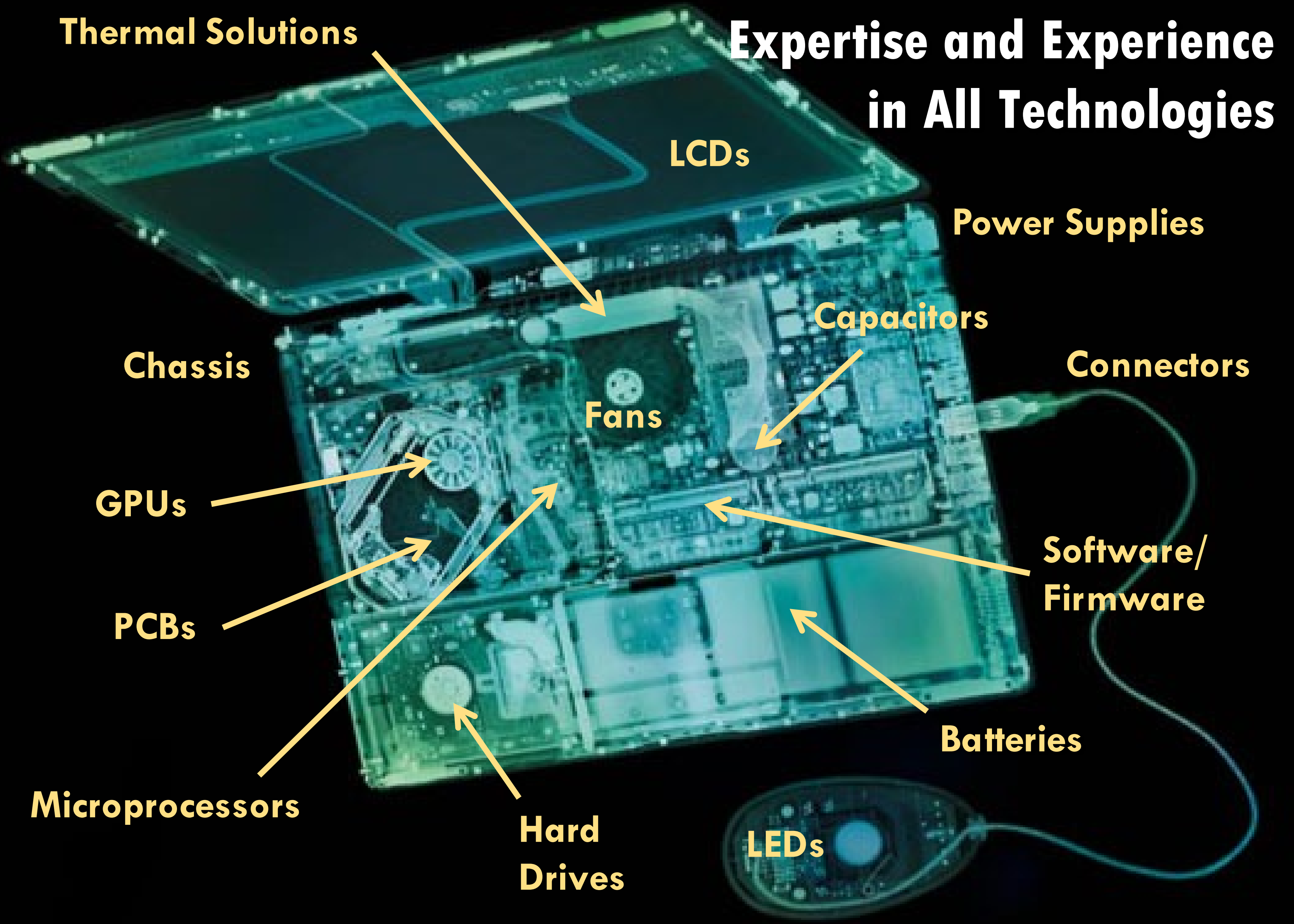
12 Years of Providing Solutions to the Electronics Marketplace



End-to-End Quality and Reliability Expertise

- DfR / DfM / DfX
- 3rd Party Design Review
- Failure Analysis
- Root Cause Investigations
- Forensic Engineering
- Circuit Analysis
- Connector/Wiring Selection
- Analog/Power Design
- Material Characterization
- PCB / PCBA Onsite Audits
- Pottings and Coatings
- FMEA / FTA
- Finite Element / Fluid Dynamics
- Physics of Failure Modeling

Expertise and Experience in All Technologies



Thermal Solutions

LCDs

Power Supplies

Capacitors

Chassis

Connectors

Fans

GPUs

Software/ Firmware

PCBs

Batteries

Microprocessors

Hard Drives

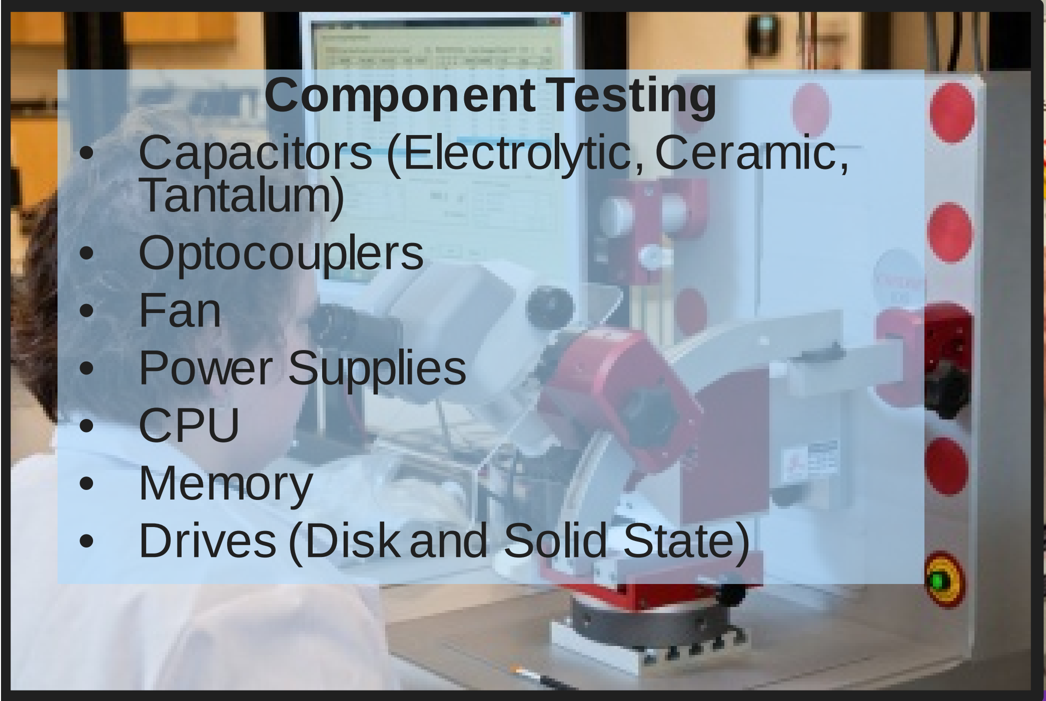
LEDs

ENGAGED WITH ALL LEVELS OF SUPPLY CHAIN

Lab and Test Capability

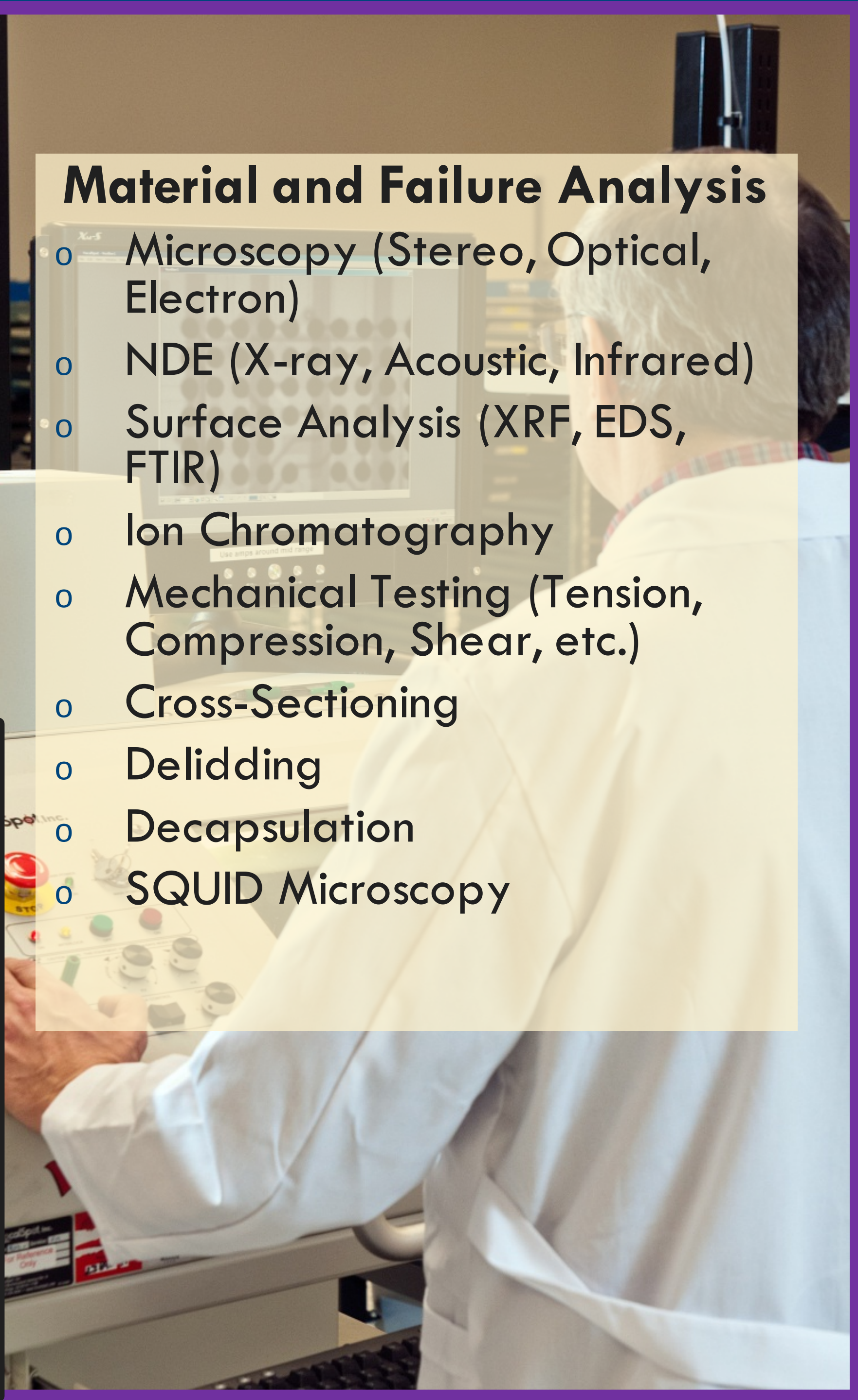
Over 25 environmental chambers

- Temp Cycling, Temp/Humidity
- Walk In
- -200C to 1500C
- Vibration + Temperature
- Mech Shock / Drop
- Bend Testing (Cyclic & Overstress)



Component Testing

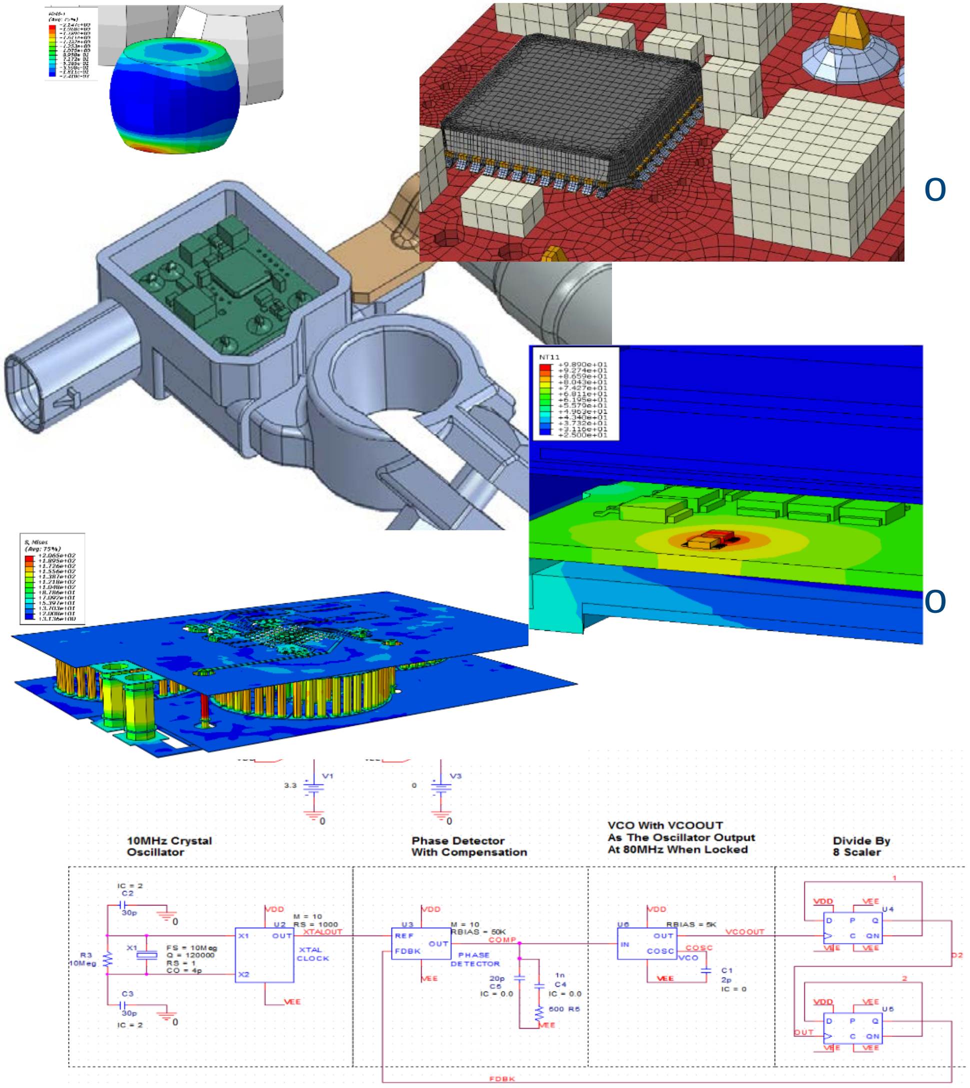
- Capacitors (Electrolytic, Ceramic, Tantalum)
- Optocouplers
- Fan
- Power Supplies
- CPU
- Memory
- Drives (Disk and Solid State)



Material and Failure Analysis

- Microscopy (Stereo, Optical, Electron)
- NDE (X-ray, Acoustic, Infrared)
- Surface Analysis (XRF, EDS, FTIR)
- Ion Chromatography
- Mechanical Testing (Tension, Compression, Shear, etc.)
- Cross-Sectioning
- Delidding
- Decapsulation
- SQUID Microscopy

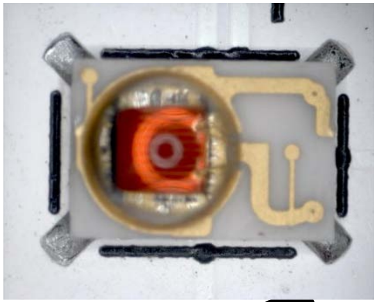
EXAMPLE ACTIVITIES

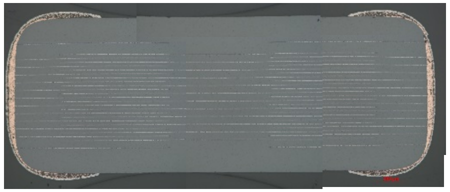


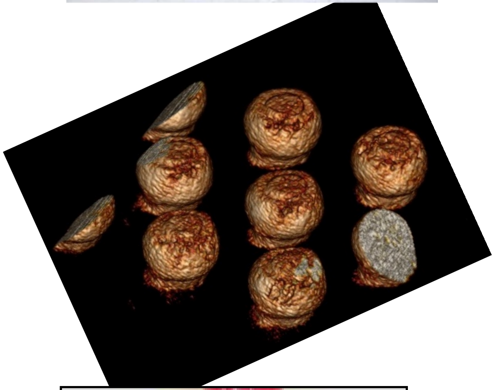
Simulation and Modeling

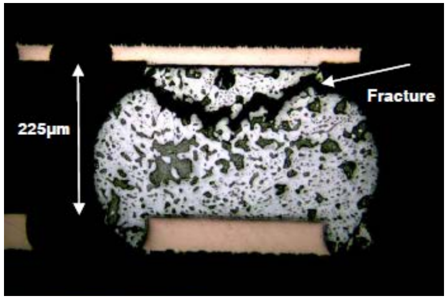
- DfR is capable of performing thermal, mechanical, and electrical simulations and extracting the results into a time-to-failure prediction
- We have developed specific algorithms and software tools relevant to electronic packaging and interconnects, power devices, and digital integrated circuits

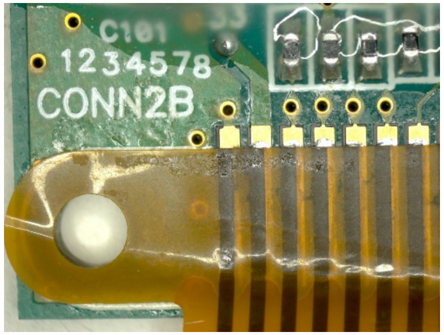
EXAMPLE ACTIVITIES (CONT.)











Root Cause Analysis and Corrective/Preventative Action

- DfR goes beyond ‘picture and an arrow’
- Capable of investigating all electronic failures and providing recommendations on appropriate mitigations
- Based on experience and deep understanding of physics of failure

RESULTS: OVER 1000 SATISFIED CUSTOMERS

Continental

SPACEX

SIEMENS

Microsoft

Medtronic

AMD

intel

Schlumberger

SUNPOWER

PHILIPS

DELPHI

BOSE

amazon

GM

TESLA

TESLA MOTORS

NVIDIA

Google

hp

DELL

MAGNA

CREE

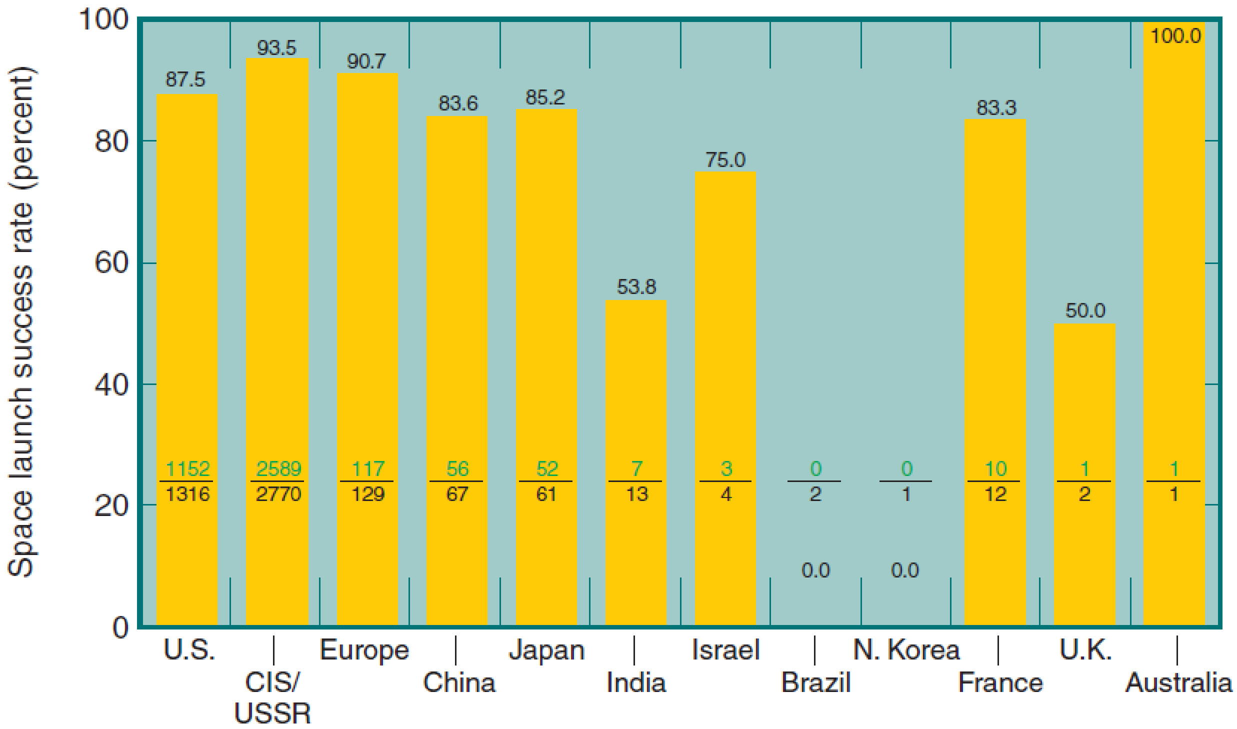
QUALIFICATION FOR COMMERCIAL SPACE SYSTEMS

Part Qualification and Small Missions

- Is there a need to continue to use 'Class S qualified' parts for Small Missions (i.e., CubeSats)?
- The primary driver for part qualification, outside of manned space systems, is reliability and cost
- Given the expected technology in Small Missions (COTS parts and boards) and size/weight, what reliability is sufficient and what expenditure can be justified based on cost?

What is Launch Reliability?

- Studies have demonstrated that launch reliability has stayed relatively constant over the past twenty (20) years
  - Between 2 to 5% failure rate per launch



- *How much more reliable do Small Missions need to be?*

What is COTS Reliability?

- Small Missions are expected to be comprised of COTS technology to keep costs reasonable
- A decision on if and how to qualify these technologies can be partially based on their field performance
- While true field performance of COTS parts is difficult to obtain (don't always believe the parts suppliers), there is publically available data on assemblies fabricated from COTS parts

COTS Reliability: Automotive Modules

- The performance of automotive electronic modules in propulsion and safety is typically less than one (1) incident per thousand (IPTV) in the first 1-3 years

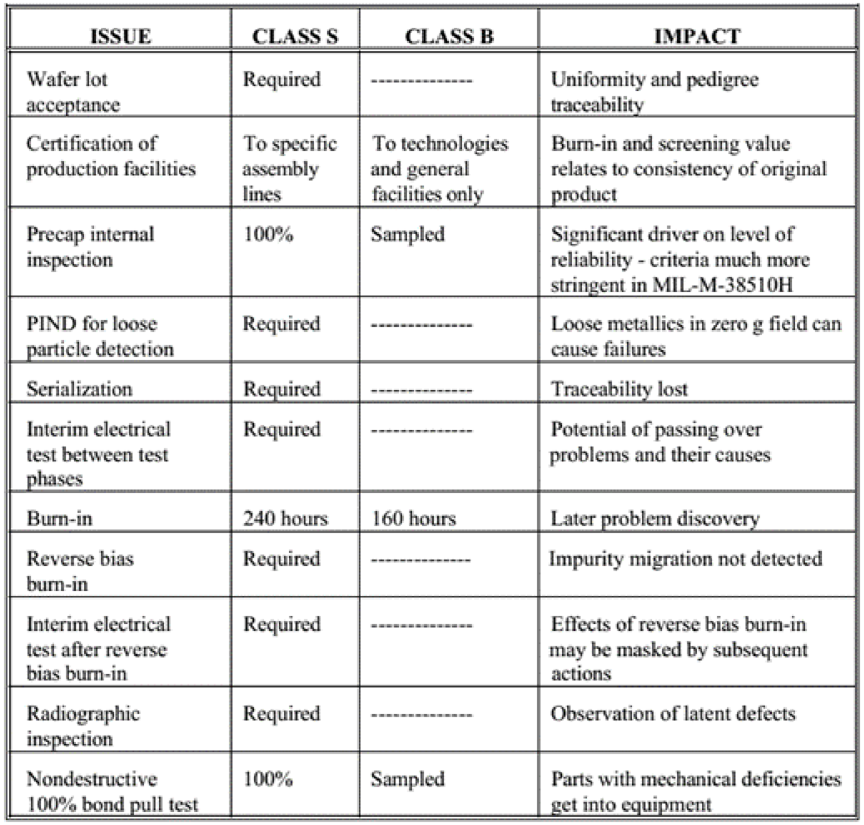
- Examples

Hyundai Brake Module:	0.3 IPTV (99.97%)
GM Antilock Brake Module:	0.03 IPTV (99.997%)
Nissan Transmission Controller:	0.6 IPTV

What are Alternative Methods to Qualify EEE Parts?

CLASS S PARTS REQUIREMENTS vs COMMERCIAL AUTOMOTIVE

- Extended temperature range: -55°C to 125°C or wider
- Hermetic packaging (i.e. solid state relays and monolithic ICs)
- Higher vibration capability
- Control of outgassing and flammability
- Low defect levels (10ppm) and high reliability (1 to 15 FITs)
- Conservative derating and application practices
- Radiation hardening
- It should be noted that some of the demanded defect levels of space grade parts are higher than the defect levels expected and delivered in some commercial applications



ISSUE	CLASS S	CLASS B	IMPACT
Wafer lot acceptance	Required	--------------	Uniformity and pedigree traceability
Certification of production facilities	To specific assembly lines	To technologies and general facilities only	Burn-in and screening value relates to consistency of original product
Precap internal inspection	100%	Sampled	Significant driver on level of reliability - criteria much more stringent in MIL-M-38510H
PIND for loose particle detection	Required	--------------	Loose metallics in zero g field can cause failures
Serialization	Required	--------------	Traceability lost
Interim electrical test between test phases	Required	--------------	Potential of passing over problems and their causes
Burn-in	240 hours	160 hours	Later problem discovery
Reverse bias burn-in	Required	--------------	Impurity migration not detected
Interim electrical test after reverse bias burn-in	Required	--------------	Effects of reverse bias burn-in may be masked by subsequent actions
Radiographic inspection	Required	--------------	Observation of latent defects
Nondestructive 100% bond pull test	100%	Sampled	Parts with mechanical deficiencies get into equipment

Class S versus AEC-Qxxx

				Xilinx	Xilinx	Linear Technology	Linear Technology	On- Semi	International Rectifier	International Rectifier
Step	Baseline Screen	883 Method	Requirement	V-flow Space qualified ceramic per Mil PRF 38510	Automotive - plastic per AEC specs	Space Grade	Automotive Grade 1	Automotive Grade	Automotive Grade	Space Grade
1	Destructive In-Line Bond Pull	Method 2011, Condition D	sample	in-line SPC, a significant advantage over lot sampling	SPC sample once per shift per bonder	100% non-destructive bond pull per MIL-STD 883 Method 2023	MIL-STD-883 Method 2011- 30 bonds per shift	not performed		Process Monitor MIL-STD-883, Method 2023
2	Internal Visual	Method 2010, Condition A	100%	Method 2010, condition B	Commercial visual	100% pre seal visual per MIL-STD-883 Method 2010, Condition A (Note1)	not performed	not performed		100% MIL-STD-883, Method 2010 Condition A
3	Serialization		100%	100%	not done	100%	not done	not performed		100%
4	Temperature Cycling	Method 1010, Condition C	100%	Method 1010, Condition C	lot sample, condition C	100% MIL-STD-883, Method 1010, Condition C	per JESD22 A 104-sample 77 plus power temp cycle per A-105 - 77 sampples	77 units/lot 500 cycles -55 to 150C	77 units/lot 1000 cycles -55 to 150C	100% MIL-STD-883, Method 1010 Test Condition C
5	Constant Acceleration	Method 2001, Condition B or D, Y1 Orientation Only	100%	Method 2001, Condition B or D, Y1 Orientation Only	not applicable	100% MIL-STD-883, Method 2001, (y1 Only) Condition E (TO3 package, Condition D)	not done	hermetic packages only		100% MIL-STD-883, Method 2001, Test Condition E
6	Particle Impact Noise Detection	Method 2020, Condition A	100%	Method 2020, Condition A	not applicable	100% PIND Test per MIL-STD-883, Method 2020, Condition A	not done	not performed		100% MIL-STD-883, Method 2020 Test Condition A
7	Radiographic	Method 2012 (one view only)	100%	lot sample in-line and at DPA	not done	100% per MIL-STD 883, Method 2012, 2 views	not done	not performed		100% per MIL-STD 883, Method 2012

Class S versus AEC-Qxxx

8	Pre-Burn-In Test	In accordance with applicable Vendor "A" device specification	100 %	In accordance with SMD	not done	100%	J-STD-020 sample size 77	not performed		100%
9	Dynamic Burn-In	Method 1015, Condition D, 240 hours at 125°C or 120 hours at 150°C minimum	100 %	1015, Condition D, 240 hours at 125°C or 120 hours at 150°C minimum	not done	100% per MIL-STD-883, Method 1015 240 hours at 125C	High Temperature Operating Life - per JESD22 A108 sample size 77	77 samples 504 hours 150C	HTOL, 3 lots, 77 samples, 125C 1000 hours or 500 hours at 150C	100%, 240 hours, MIL-STD-883, Method 1015
10	Interim (Post-Burn-In) Electrical Parameters	In accordance with applicable Vendor "A" device specification	100 %	In accordance with SMD	not applicable	100% test at 25C, 125C and -55C	not done	not performed		100%
11	Static Burn-In	Method 1015, Condition C, 72 hours at 150°C or 144 hours at 125°C minimum	100 %	Method 1015, Condition C, 72 hours at 150°C or 144 hours at 125°C minimum	not done after qualification per AEC specs	100%, Method 1015, Condition A or C, 72 hours min at 150°C	not done	not performed		
12	Interim (Post-Burn-In) Electrical Parameters	In accordance with applicable device specification	100 %	In accordance with SMD	see AEC specs	100% In accordance with applicable device specification	not done	not performed		
13	Percent Defective Allowable (PDA) calculation	5%, 3% Functional Parameters at 25°C	All lots	All lots	see AEC specs	5%, 3% Functional Parameters at 25°C	not done	not performed		5%
14	Final Electrical Test	In accordance with applicable device specification which includes a, b and c	100 %	100%	100%	100%	100%	100%		100%

Class S versus AEC-Qxxx

15	Seal	Method 1014	100%	100%	not applicable		not applicable		
	a. Fine				not applicable	100% per MIL-STD -883, Method 1014, Test condition A	not applicable	hermetic packages only	100% per MIL-STD -883, Method 1014, Test condition A
	b. Gross				not applicable	100% per MIL-STD -883, Method 1014, Test condition C	not applicable	hermetic packages only	100% per MIL-STD -883, Method 1014, Test condition C
16	External Visual	Method 2009	100%	Method 2009	comercial spec	100% per MIL-STD-883 Method 2009	package dimensions (SS2), external visual(SS45), marking permanency(SS3), solderability(SS3), die attach quality9SS11), lead fatigue(SS10)	Construction Analysis	100% per MIL-STD-883 Method 2009

Class S versus AEC-Qxxx

Linear Technology Automotive Grade 1	On-Semi Automotive Grade	International Rectifier Automotive Grade
Temp/Humidity Bias SS45 JESD22 A101	77 samples 168 hours 85C 60% RH	3 lots of 77 samples 1000 hours85C 85RH
Unbised HAST - JESD22 A102, SS77		0r 96 hours 130C-85%RH,18.6psi
High Temp Storage Life JESD A103 SS77	77 units 1008 hours 150C	1 lot - 45 samples, 150C 1000 hours
Early Life Failure Rate AEC-Q100-008	800 units/lot 48 hours 150C	3 lots x 800 samples - biased up to 100%, 125C 48 hours
NVM Endurance AEC-Q100-005 SS77	77 units/lot 1008 hours 150C	
Solderability JESD22 B102 SS15		
Physical Dimensions JESD22 B 100 SS10		
Lead Integrity JESD22 B105 or Solder Ball Shear AEC-Q100 SS5x10		
		power temperature cycle -40C to 125C 1000 cycles 1 lot 77 samples
		Unbiased autoclave 121C, 15psi, 100%RH, 3 lots 77 samples
Die Tests	Die Tests 3 lots mandatory	
TDDB	TDDB	
Hot Carrier Injection	Hot Carrier Injection	
Negative Bias Temp Instability	Negative Bias Temp Instability	
	Capacitor Dielectric	
	Plasma Process Induced Stress	
	Metal/Dielectric Integrity	
	Bias Temp Stress	
Stress Migration	Stress Migration-1 lot	
Electrical Verification		
ESD Human Body - AEC Q100-002 and 003	5 units/lot	
	ESD Machine model 5 units/lot	
ESD Charged Device - AEC Q100-011	5 units/lot	
Latch Up-AEC-Q100 004	5 units/lot	
Electrical Distributions AEC-Q100 009		
Fault Grading - AEC-Q100 007		
Characterization AEC-Q003		

Class S versus AEC-Qxxx

	Gate leakage - AEC-Q100 006		
	EMC Compatibility SAEJ1752/3		
	Short Circuit Characterization AEC-Q100 012		
	Soft Error Rate JESD89-1/2/3		
	Process Avg Testing AEC-Q001		
	Statistical Bin Analysis AEC-Q002		
		Mechanical Shock - hermetic packages only	
		Vibration - hermetic packages only	

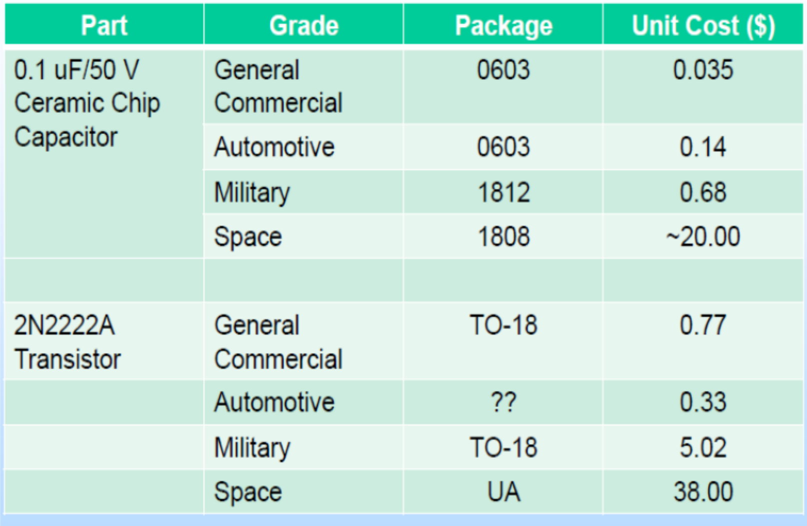
What is Automotive Grade?

- Automotive grade should mean
  - Tested to one of the AEC qualification documents (Q100, Q101, Q200)
    - Includes rigorous process change notification
  - Certified to ISO/TS-16949
    - Requires a Production Part Approval Process (PPAP)[typically compliant to AIAG manual]; PPAP would include PFMEA, control plan, drawing, MSA, capability data, etc
  - Commitment to Zero-Defect

- In actuality, automotive grade means different things to different component suppliers (there is no standard)

CONCLUSIONS FROM DFR SURVEY OF ASSEMBLY COMPANIES

- We found that assembly companies supplying to the automotive industry already go beyond class S requirements for the most part
- Automotive conditions are more stringent than space in terms of temperature (except during launch), vibration and shock
- Exceptions are radiation hardening
- Space grade components can cost 100X to 1000X more than functionally equivalent commercial or automotive grade components



Part	Grade	Package	Unit Cost ($)
0.1 uF/50 V Ceramic Chip Capacitor	General Commercial	0603	0.035
	Automotive	0603	0.14
	Military	1812	0.68
	Space	1808	~20.00
2N2222A Transistor	General Commercial	TO-18	0.77
	Automotive	??	0.33
	Military	TO-18	5.02
	Space	UA	38.00

Concerns with Radiation

- Reliability by similarity (RBS)
  - Future efforts can focus on part technology, especially power and analog, instead specific components

- With evidence that newer digital semiconductor devices are more tolerant to Total Dose (TID), focus on fault tolerant system for single event effects (SEE)
  - Software, shielding, supporting external circuits, etc.

Concerns about Quality

- The quality levels of certain COTS parts and assemblies may already be sufficient

- It has been DfR Solutions experience with passive and discrete devices that the quality levels of top tier suppliers is higher than from lower tier suppliers that offer screening levels

- Case Study: Project with medical device OEM found commercial-grade ceramic capacitors had higher incoming quality than similar devices subjected to medical or military grade screening

Concerns about Reliability

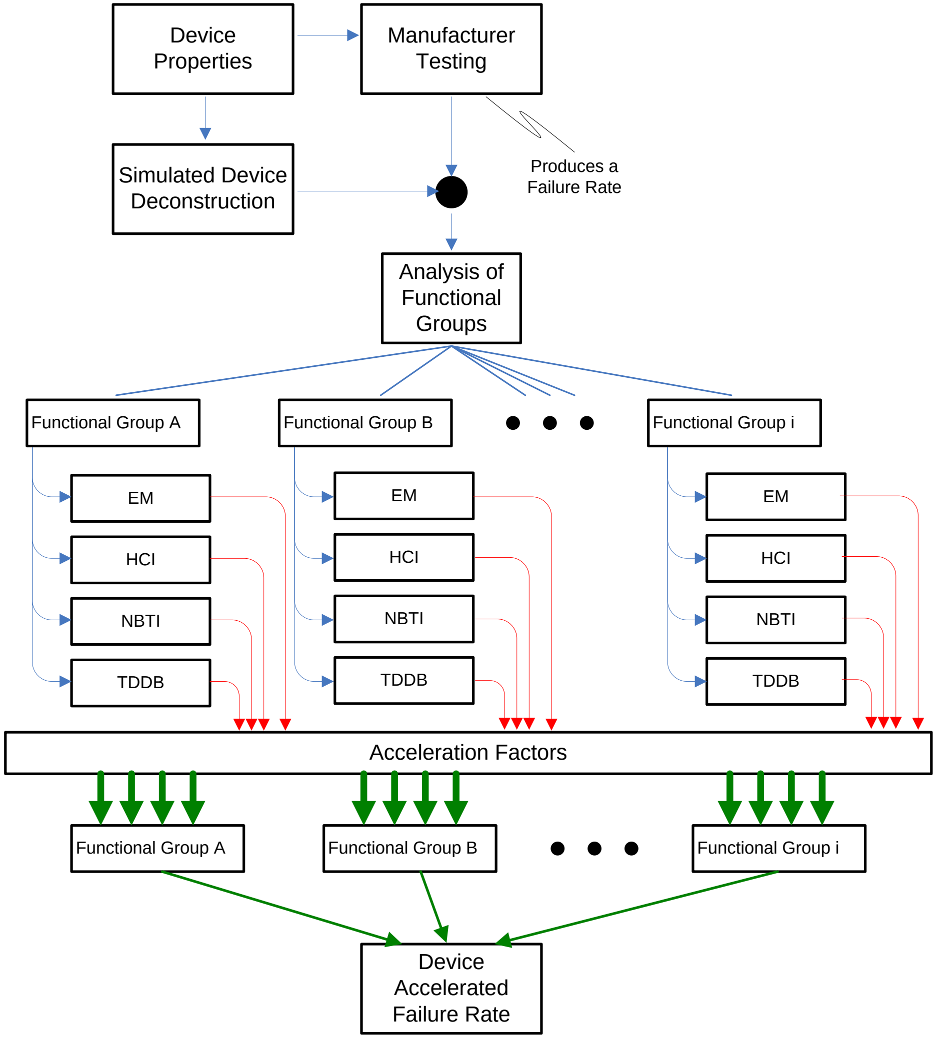
- Most Small Missions are likely to have brief lifetimes
  - 1 month to 1 year
  - A focus on long-term reliability, even under the extremes of space environment, may not be relevant

- Recent focus on high performance mobile applications can help extend lifetimes
  - Lower voltage, lower power reduces stress on active regions within the digital device

- When Small Missions have longer lifetimes, simulation may need to accentuate or replace actual testing
  - Both at part and assembly level

Integrated Circuit Reliability: Multi-Mechanism

Approach



Device Properties

Manufacturer Testing

Simulated Device Deconstruction

Produces a Failure Rate

Analysis of Functional Groups

Functional Group A

Functional Group B

Functional Group i

EM

HCI

NBTI

TDDB

Acceleration Factors

Functional Group A

Functional Group B

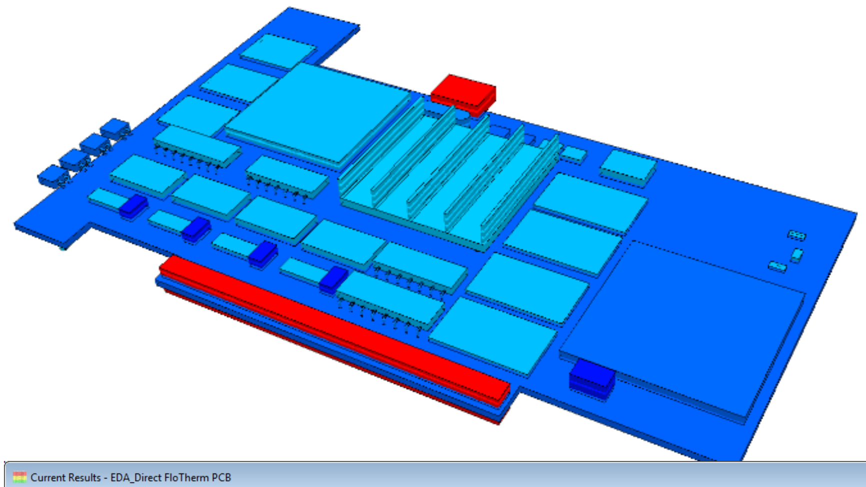
Functional Group i

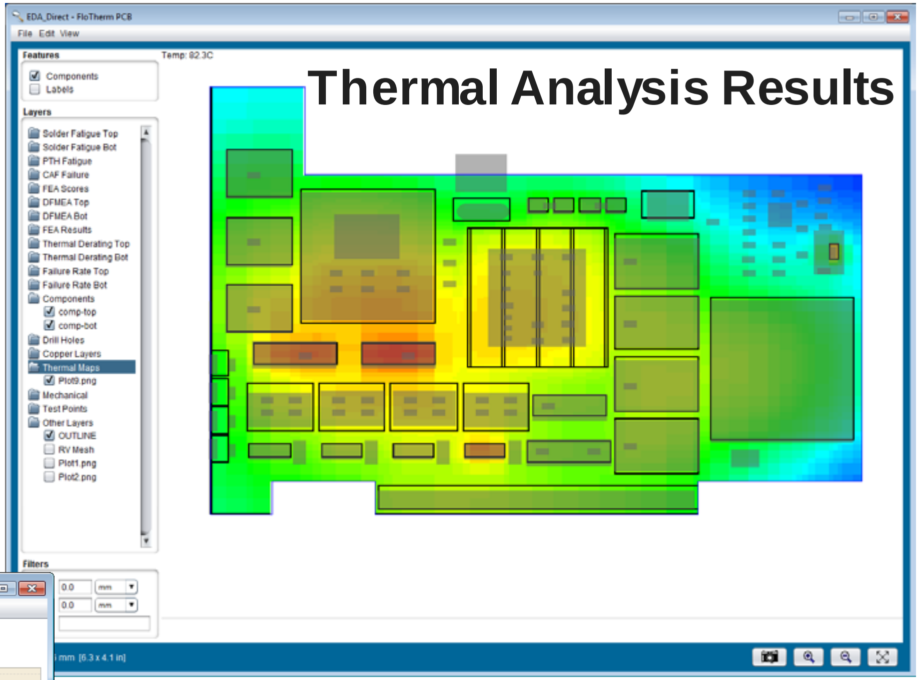
Device Accelerated Failure Rate

- Models simultaneous degradation behaviors of multiple failure mechanisms on integrated circuit devices
- Devised from published research literature, technological publications, and accepted degradation models from:
  - NASA\JPL
  - Semiconductor Reliability Community

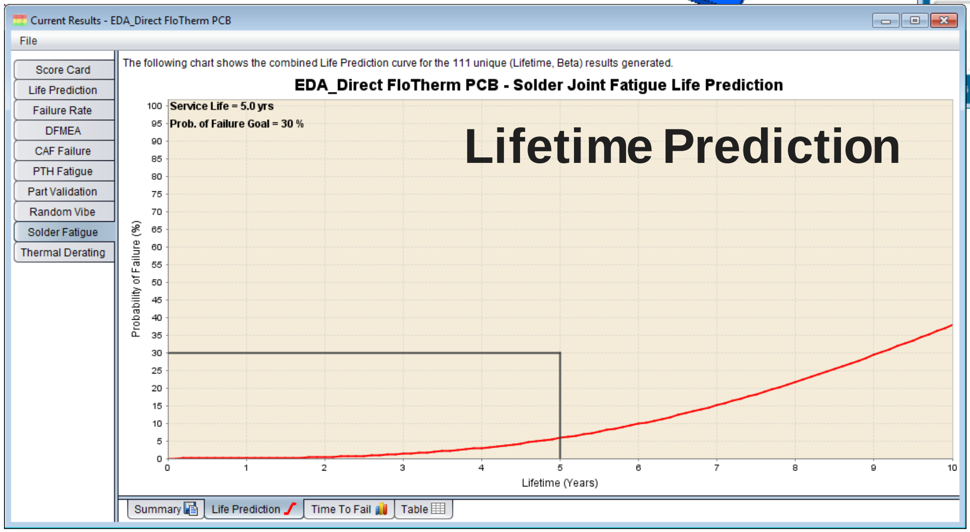
Assembly-Level Reliability – Virtual Power Cycling

3D Sherlock Model





Thermal Analysis Results



Lifetime Prediction

Current Results - EDA_Direct FloTherm PCB

The following chart shows the combined Life Prediction curve for the 111 unique (Lifetime, Beta) results generated.

EDA_Direct FloTherm PCB - Solder Joint Fatigue Life Prediction

Service Life = 5.0 yrs
Prob. of Failure Goal = 30 %

- EDA → Sherlock → Flotherm → Sherlock → Prediction: 8 hours

Conclusion

- Small Missions offer a great opportunity for the Space Community
- Success is dependent robust EEE systems within a particular cost and time envelope
- There are opportunities and techniques that allow for robust EEE systems when leveraging existing knowledge and good engineering judgment
    - What is the environment?
    - What is the necessary reliability?
    - What is the budget?