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reliability designed, reliability delivered

Alternative Methods to Qualify EEE parts for Small Missions

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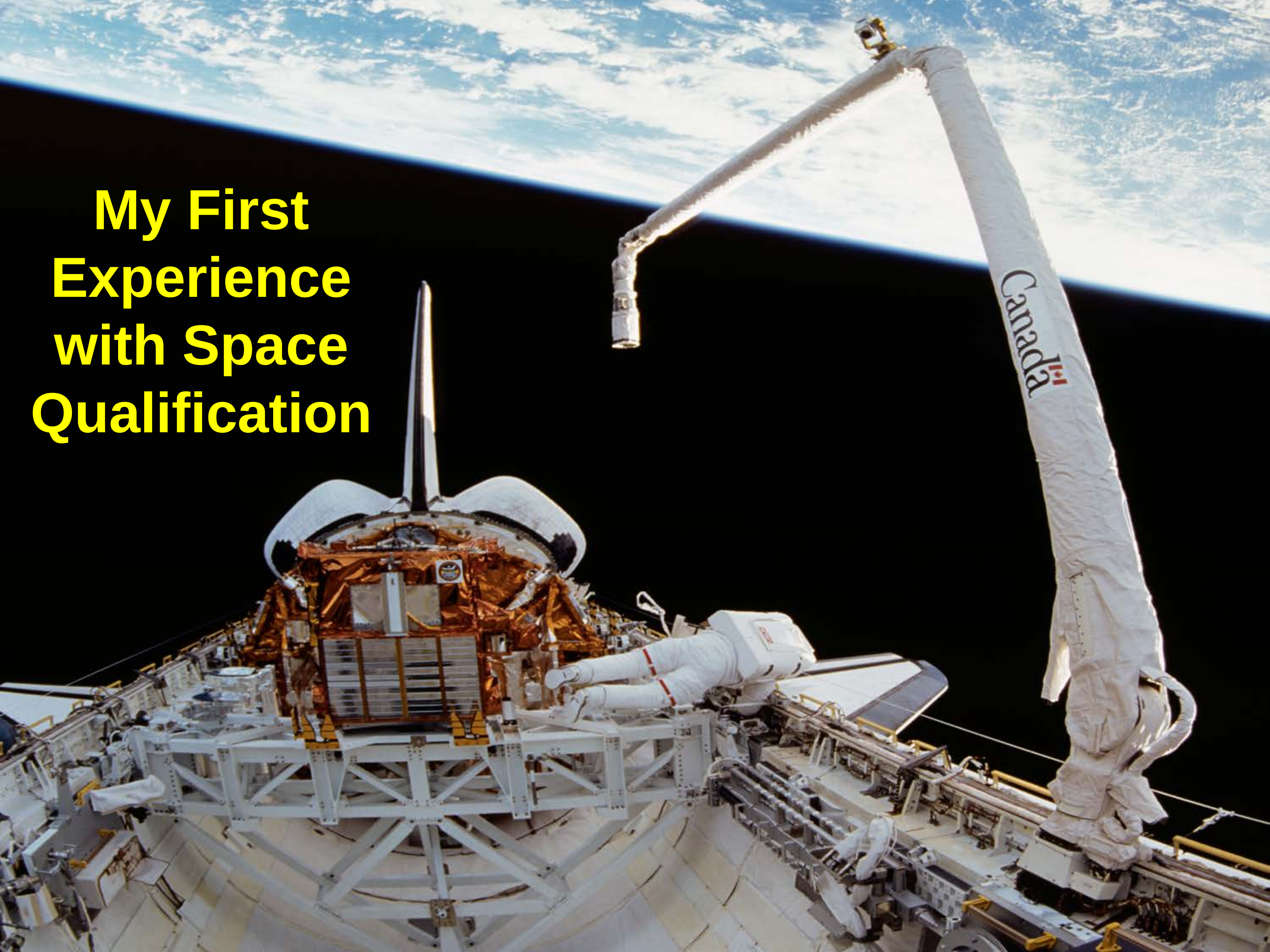
September 10, 2014 NASA Goddard Greenbelt, MD

My First Experience with Space Qualification



Part Qualification

- What is Qualification?
  - Typically a series of physical tests designed to assess robustness or suitability

- Why Do We Qualify Electronic Parts?
  - Conditions not considered by the manufacturer (radiation, outgassing)
  - Conditions beyond the manufacturer's specifications (temperature)
  - Concern about overall quality / robustness

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Part Qualification (cont.)

- Sometimes, qualification is combined with screening to create ‘**qualified**’ parts or parts of a certain ‘**grade**’

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Space Qualified

The TriQuint products listed below have been qualified for space applications. Qualification includes high-level visual inspection, 100% element electrical results, burn-in, 1000-hour life test and wafer lot qualification testing.

Most products throughout the TriQuint Product Selection Guide may be considered for qualification. The product tables below contain a subset of our products, fabricated with various production processes, that have been space qualified. Refer to the FAQs on the Space page and the Space Qualification Process document in the Resources library for more information. Contact TriQuint prior to designing any of these parts into your space application as certain conditions apply.

TriQuint offers testing that is compliant in these categories:

Test	Method / Condition
Bond Strength	2011/D
Visual Inspection	2010/A
Temperature Cycling	1010/C

Key Benefits

- Proven reliability including data to predict MTTF and/or FITs
- Radiation hardness
- Ability to deliver as 100% electrically tested
- Ability to deliver as 100% space visually inspected (per MIL-STD-883 Method 2010, Condition A)
- Ability to deliver as space qualified (per the intent of MIL-PRF-38534 for die)

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Monolithic Ceramic Capacitors FAQ

Characteristics • Part Names

Q. What is the difference between Automotive Grade (GCM) and standard grade (GRM) capacitors?

A. Applications

The GCM Series, which has higher reliability than the standard GRM, is recommended for life-critical applications, such as automotive (driving, turning, stopping, safety equipment) and medical equipment, and recommended solely for life-critical equipment. For information system such as car navigation, entertainment (such as car audio or DVD players), and body control such as wipers and power windows, the GRM Series is recommended.

Warranty Information

There are some differences between the GCM series and GRM series, not only in their applications but also in terms of warranty information.
The following high reliability is guaranteed in GCM series as the high reliability is required for automotive application.
The special guarantee is available for certain items, so please contact our sales representative.

Warranty Information: Comparative table of GCM series and GRM series

	GCM (AEC-Q200)	GRM
Temperature cycle	1000 cycle	5 cycle
Thermal shock cycle	300 cycle	-
Humidity Humidity load	85°C、85%、1WV 1000 hours	40°C、90%、1WV 500 hours
Low voltage humidity load (85°C 85% 1.3V)	1000 hours	-
High temperature load	1000 hours	1000 hours
Retained at high temperature	1000 hours	-
Humidity cycle	10 cycle	-

Part Qualification and Small Missions

- Is there a need to continue to use '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?

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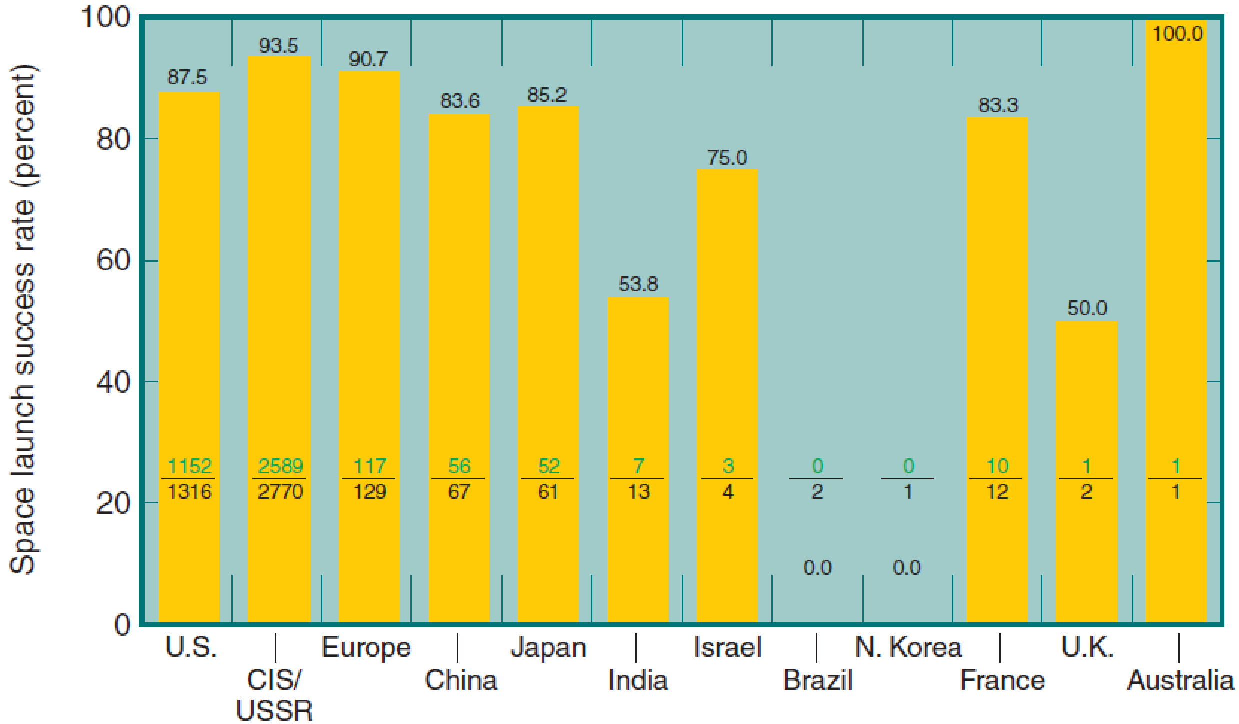
What is Launch Reliability?

- 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?*

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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

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COTS Reliability: Apple iPad2

- Much more complicated than an automotive module
  - Over 1000 components
  - Over 250 unique parts
  - Very small components: 01005, 0201, 0402, 0603
  - Almost 25 ball grid arrays (BGA) with up to 1000 I/O
- How reliable is this piece of consumer electronics?

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Warranty Returns: iPad2

Figure 2. Non-Accident Failure Reasons - iPad1 and 2

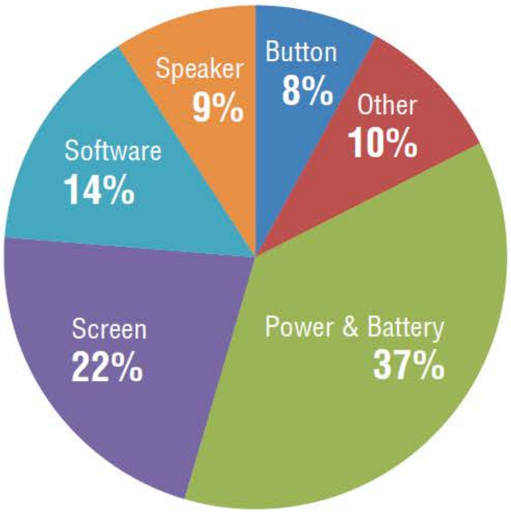
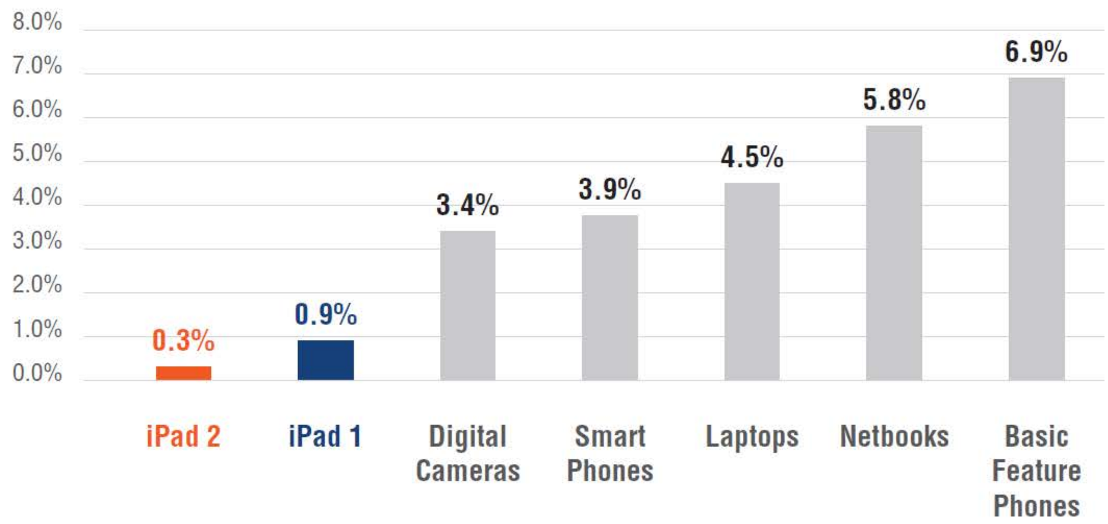


Figure 3. 12 Month Malfunction Rates of Common Portable Electronics



- Truly revolutionary: A consumer electronic as reliable (or more) than typical high-reliability electronics
  - Key Drivers: More robust software, elimination of moving parts (fans, keyboard, hard drive)
- Small Mission relevant failures drops failure rate closer to 0.1%

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iPad2: Last Point

- What does it mean if a complex piece of consumer electronics, with state of the art technology, can be 99.9% reliable (and an average component failure rate of <1 ppm) with **no** special qualification and **no** screening?

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Qualification Budget

- How much can I spend to qualify electronics for Small Missions?
  - Key issue for satellites is payload cost (weight)

- Estimates of cost-per-kilogram to launch into low-earth-orbit (LEO) range from $1500 (Falcon Heavy) to $15000 (Atlas V)(GEO 2X to 5X higher)

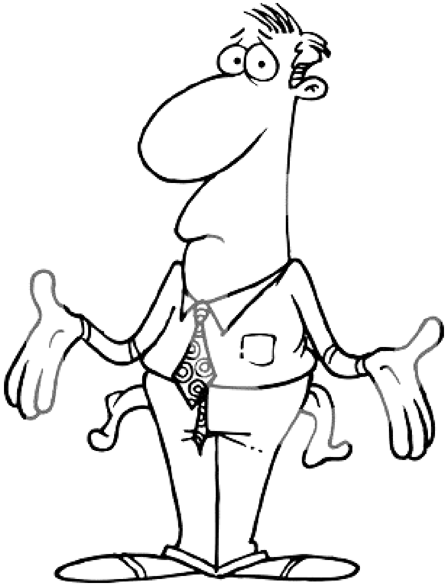
- Some definitions of CubeSat place the mass as no more than 1.33 kilograms (and the iPad2 is 0.6 kilograms)

http://www.nasa.gov/centers/marshall/news/background/facts/astp.html_prt.htm
http://space.stackexchange.com/questions/1989/what-is-the-current-cost-per-pound-to-send-something-into-leo
http://www.spacex.com/about/capabilities

Qualification Budget (cont.)

- The payload cost of a Small Mission may be no more than \$1000 to \$20000
  - Actual cost of COTS electronics may be no more than \$1-\$2K

- Hypothetical:
  - Assuming a standard engineering return on investment (ROI) of 5:1, there may be \$200 to \$4000 for a qualification activity to increase the mission reliability from 94.97% to 94.99% (assumes 5% rate of launch failure)



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What are Alternative Methods to Qualify EEE Parts?

Alternative Methods to EEE Parts Qualification

- Consider procuring known high-reliability COTS assembly
  - What can the design team do with an iPad2?
  - Or an automotive controller?
  - What can be done through software instead of hardware?

- For COTS parts, may need to evaluate lower cost methodologies
  - Radiation
  - Temperature
  - Quality
  - Reliability

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Concerns with Radiation (not a Radiation Expert)

- Reliability by similarity (RBS)
  - Future efforts can focus on part technology, especially power and analog, instead specific components
- Consider an Agile process
  - It may eventually be easier, cheaper, and more relevant to place it on the next launch and see what happens then to wait for availability at a ground facility
- 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 with Temperature (Operational)

- Focus on automotive grade
  - Slightly more expensive then commercial, but typical range is -40C to 105C (much cheaper than military or space)
- Consider testing at board level then at component level
  - HALT process
- Doesn't pass cold?
  - It might be cheaper, and more reliable, to put in a mild environmental control system than upscreening piece parts or procuring a specialized component qualified down to those temperatures

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)

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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 ceramic capacitors from Murata had higher incoming quality than similar devices subjected to medical or military grade screening

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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

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Industry Effort: Developing Reliability 'Packets'

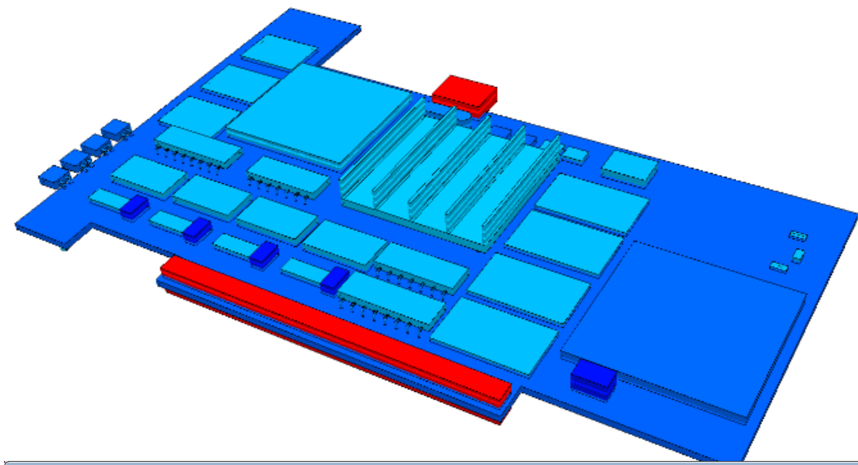
- Suppliers perform in-house EDA of their designs. Each design results in a table row of "critical constants."
  - Analysis would quantify each of the transistor stress states necessary to degrade the transistors by each applicable mechanism during typical use duty cycles

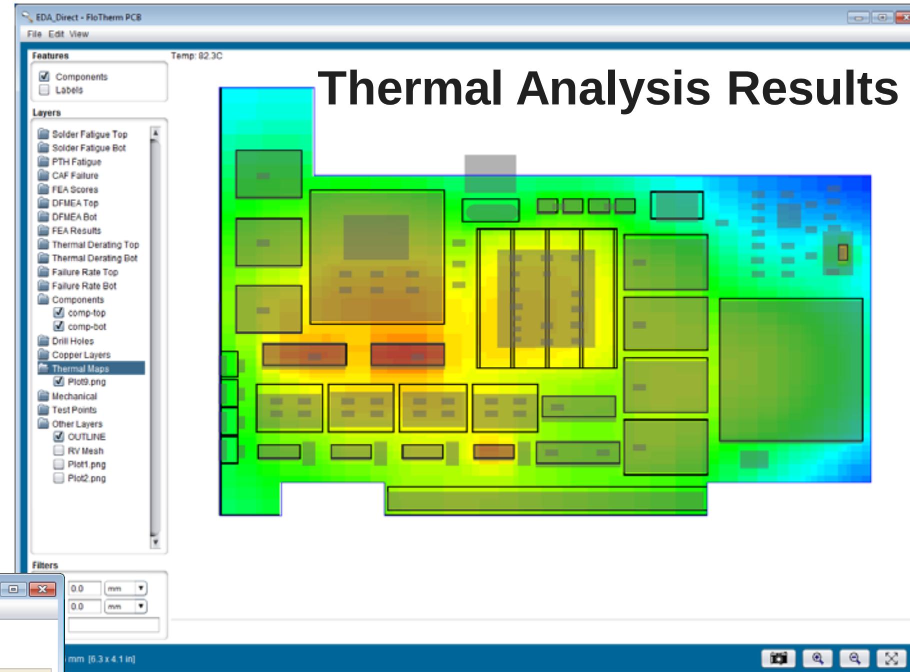
- The "counts" per failure mechanism type would be normalized for the IC or functional group within the IC (standard libraries)
  - This process would replace the current process of SPICE analysis on "assumed circuits"

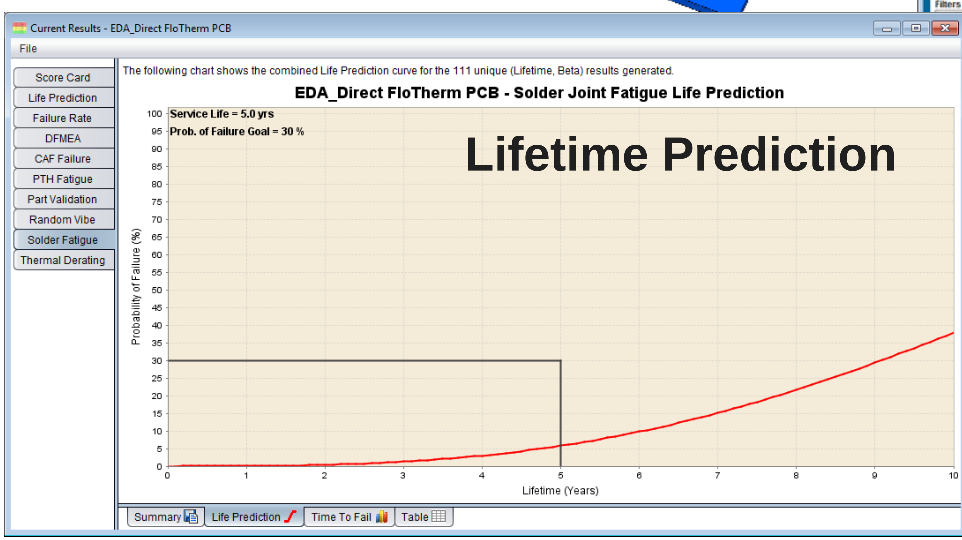
- Characterize electrical and thermal conditions of customer application and perform a prediction

Assembly-Level Reliability – Virtual Power Cycling

3D Sherlock Model







- EDA → Sherlock → Flotherm → Sherlock → Prediction: <u>8 hours</u>

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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?

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