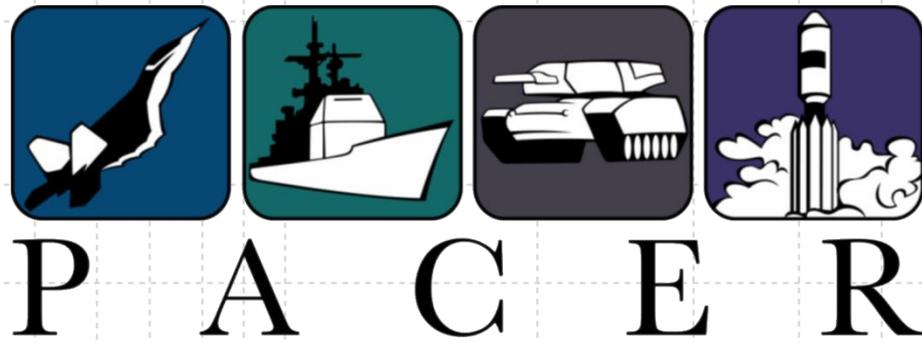




Excerpts from:
Electronics Training Course
prepared for
Naval Center for Cost Analysis

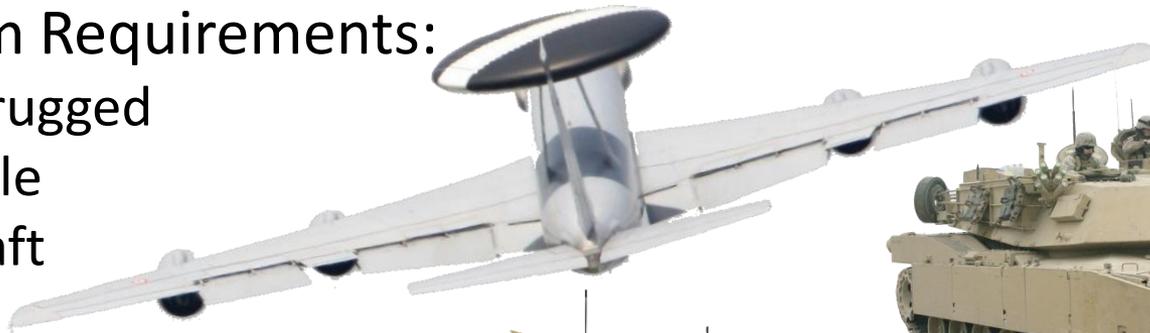
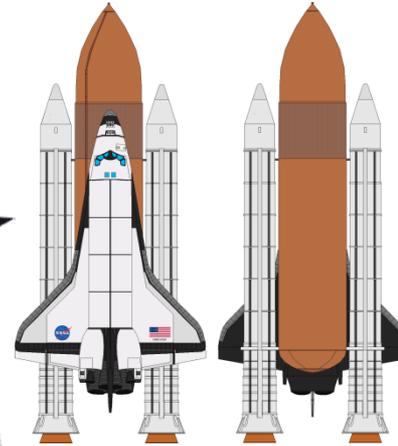
April-27-28-2016



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Ruggedization

- Shock & Vibration
- Temperature (Ceramics)
- SEU
- Cooling
- Standards
- Platform Requirements:
 - non-rugged
 - vehicle
 - aircraft
 - gun
 - missile
 - space

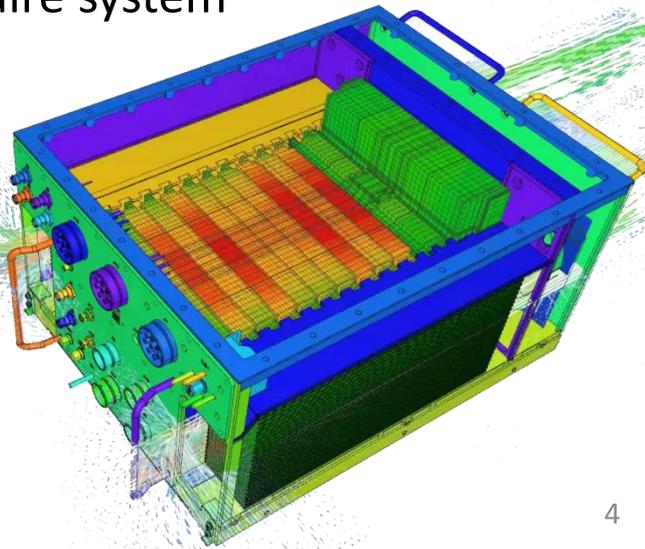
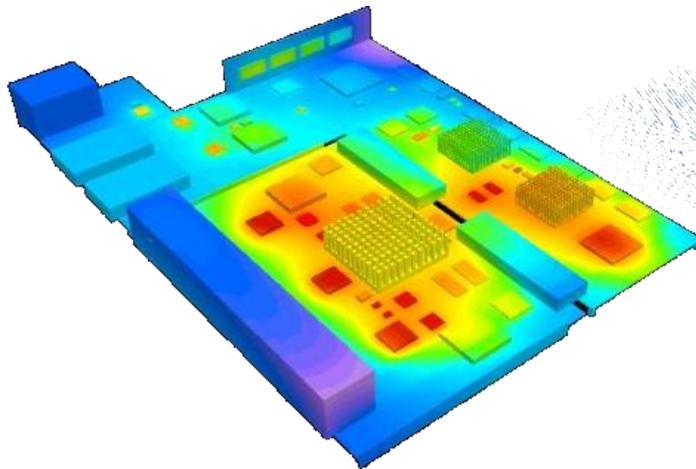
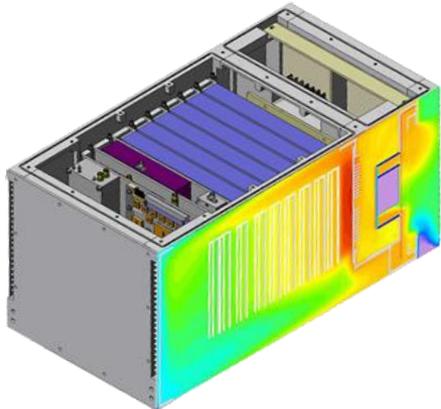


Military Standards

- Key concepts to understand with MIL-STD's
 - The standards are all about the method of testing
 - The values are set by the program requirements
 - If a missile requires -40 to +85°C and a ground vehicle requires -20 to +70°C, the method of testing is the same but the temperature values are dictated by the platform's operating environments
- Traditional cost models assume platform environments are the same
 - This leads the cost development community to build and rely on platform specific databases for modeling vs. building cross-platform models
 - There are definitely variations across platforms, for example:
 - air launched missiles vs. ground launched missiles
 - ground vehicles: tracked vehicle (tanks) vs. pneumatic wheeled vehicles
 - The cost community should QUANTIFY and MODEL the rugged requirements
 - This can result in realized reductions in modeling error values

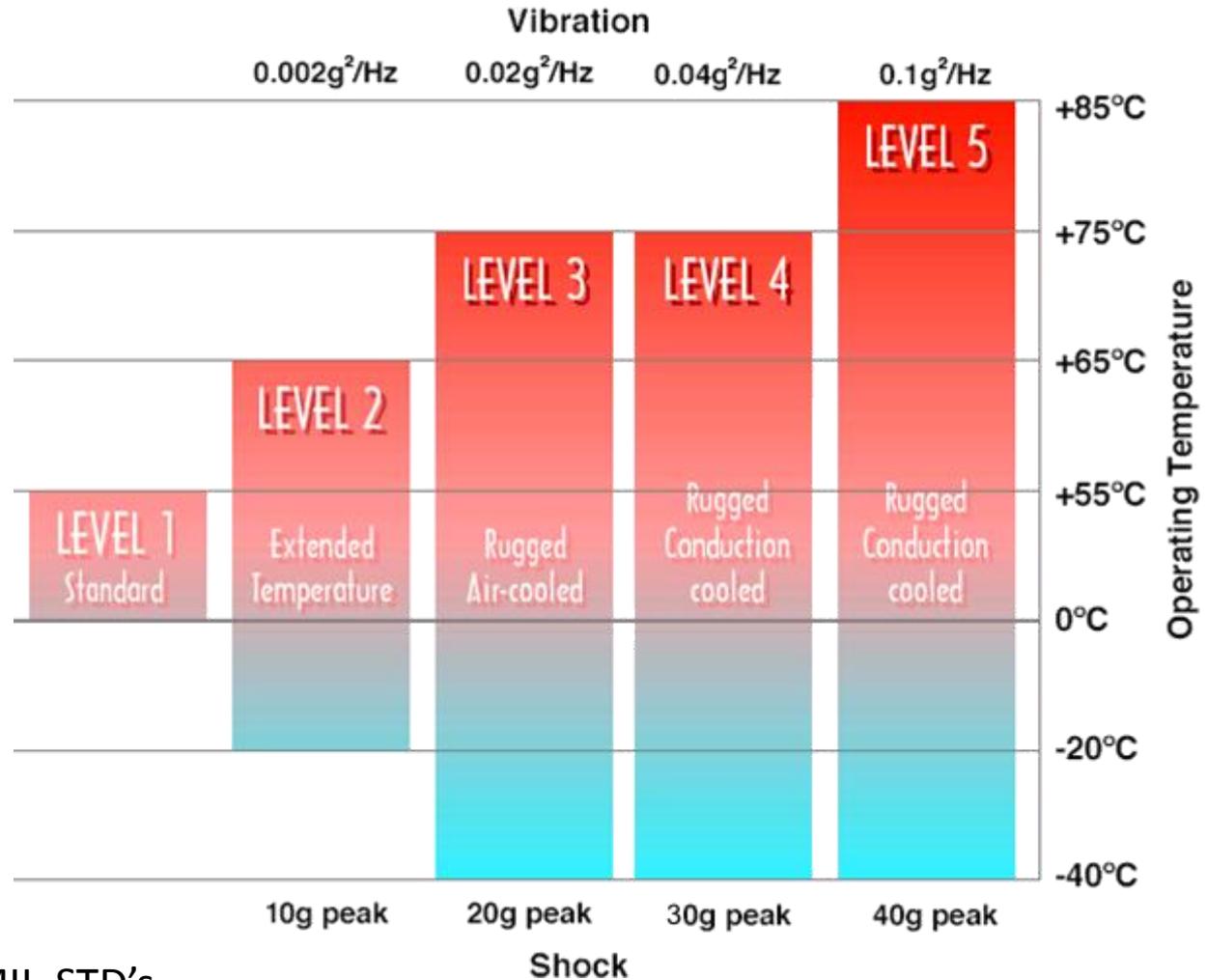
Operational Environments

- Rugged – Environmental Engineering
 - Shock
 - Vibration
 - Operational Temperature
 - Conduction vs. Air Cooled
- Below are thermal heat maps showing cooling capability
 - Boards must dissipate their heat to the card edges to then be wicked by the enclosures
 - Boards operating in close proximity may require system specific cooling accommodations



Ruggedization and Cost

- Sample Levels
 - Vibration
 - Shock
 - Temperature
 - Cooling
 - Conduction
 - Air

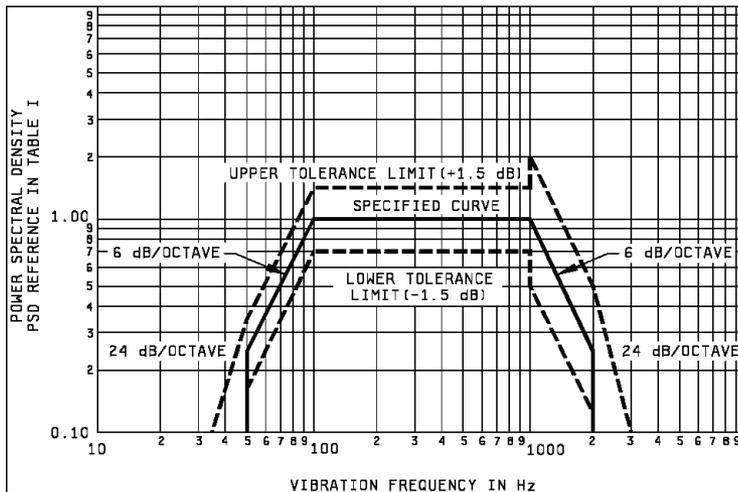


Methods for testing found in MIL-STD's such as MS-810, MS-883, MS-910

Vibration and Shock

- Vibration Power Spectral Density shown at nominal value of 1 unit. For a platform requiring $0.04 \text{ g}^2/\text{Hz}$ the curve is scaled to the requirement.

Chart is from Mil-Std-883E method 2026-1, Box at right is on shaker test table

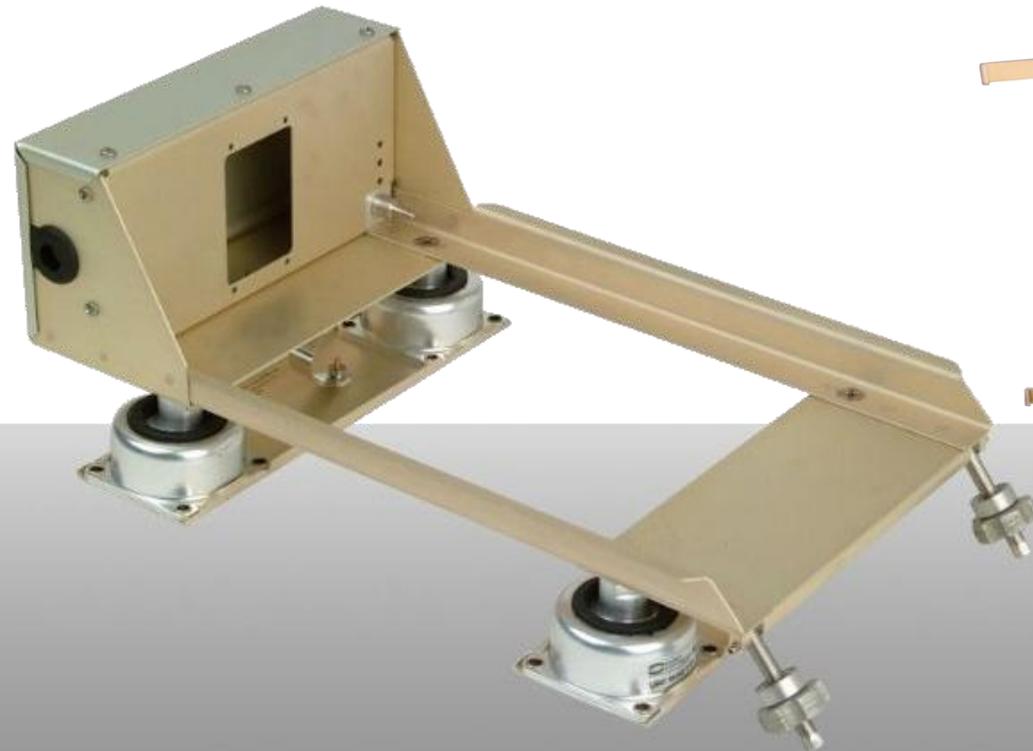


- The normal duration of measurement for shock is 11ms and is expressed as 20g, 40g, etc.

Modeling Mechanical Requirements

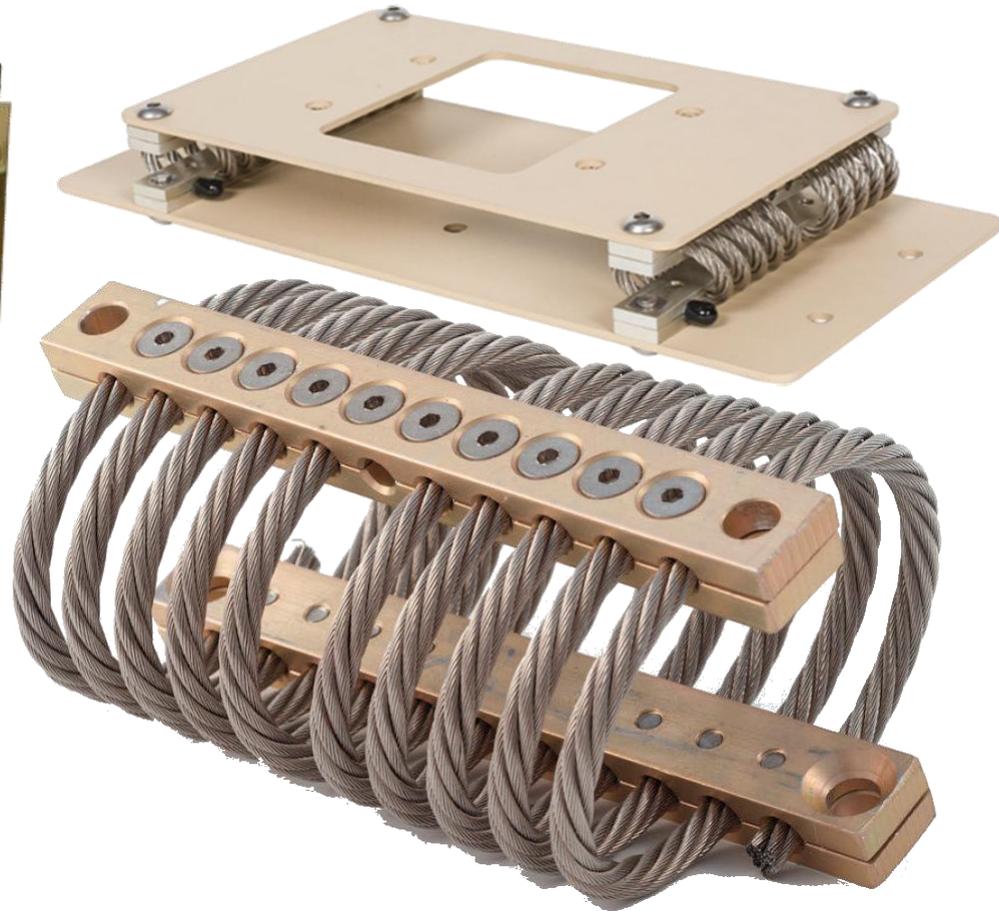
- Mounting methods (if space is abundant) can reduce operational requirements for the electrical equipment

Common isolation mounting techniques



Shock Isolation Mounting

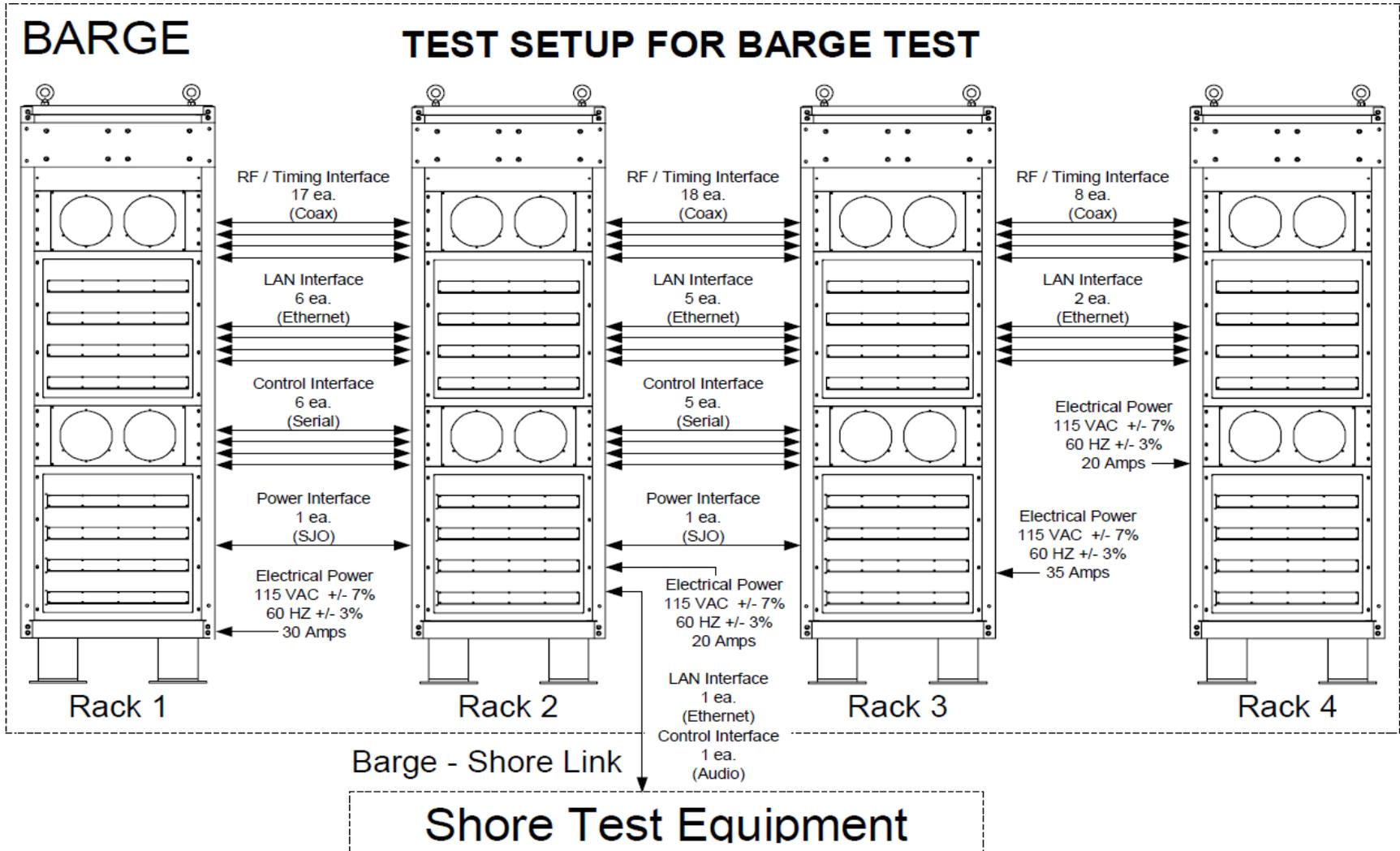
- Mounting techniques can be much less expensive than paying for ruggedized electronics inside



Stainless Steel Wire Rope Isolators

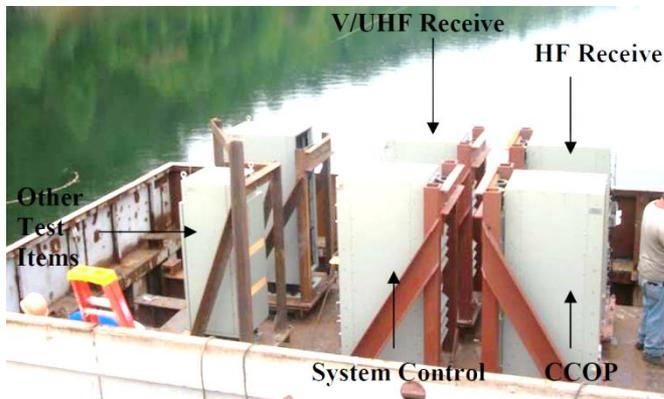
Ship Mounted IT Solutions

- Shock and Vibration Barge Testing

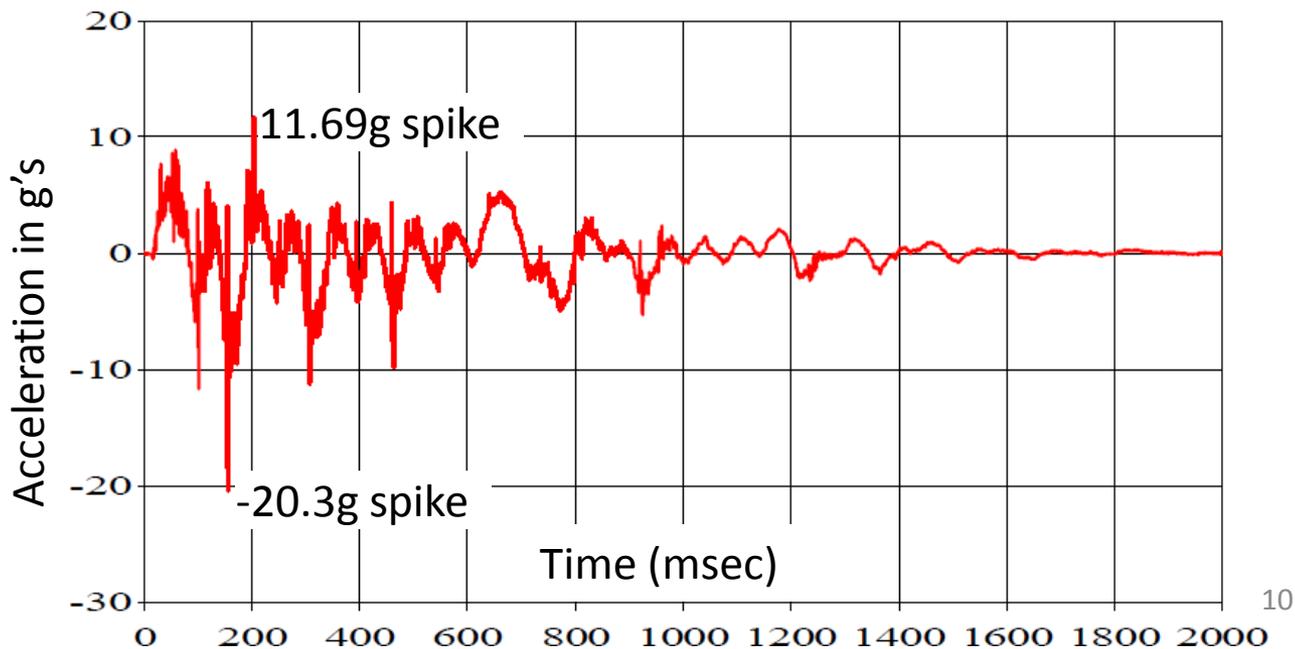


Ship Mounted IT Solutions

- Shock and Vibration Barge Testing



- Spike in graph below traced to equipment bottoming on 1st shock rebound.
- Solution realized with further internal isolation.

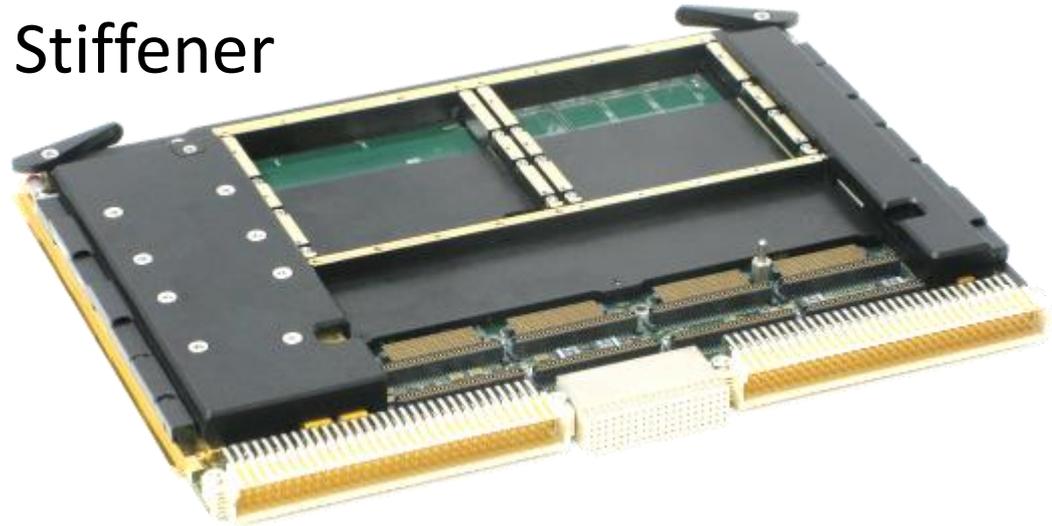


Mil-Std-810 Examples

- MIL-STD-810F High Temperature (Method 501.4)
 - Operating: Stabilized @ +80°C for 2 hours.
 - Storage: Stabilized @ +100°C for 2 hours.
- MIL-STD-810F Low Temperature (Method 502.4)
 - Operating: Stabilized @ -55°C for 2 hours.
 - Storage: Stabilized @ -55°C for 2 hours.
- MIL-STD-810F Shock (Method 516.5)
 - Operating: Exposed to 3 pulses/direction of saw tooth shock @ 40g 11ms in 6 directions.

Board Ruggedization Methods

- Machined Heat Sink and Stiffener

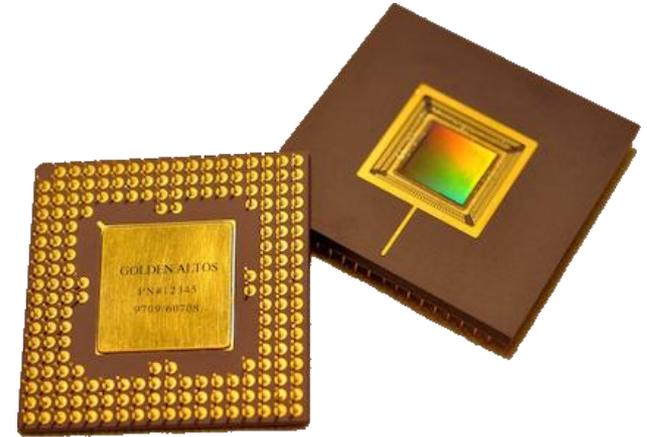
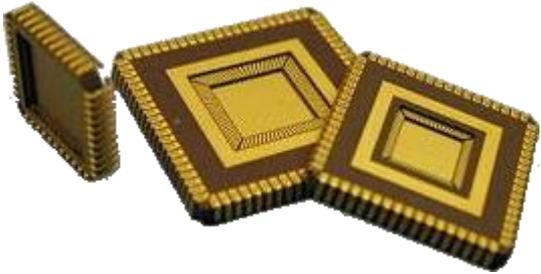


- Machined Stiffeners Only

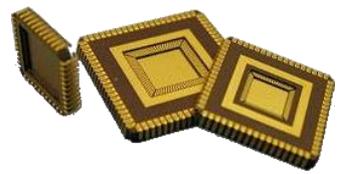


Chip Ruggedization Methods

- High Temperature Components

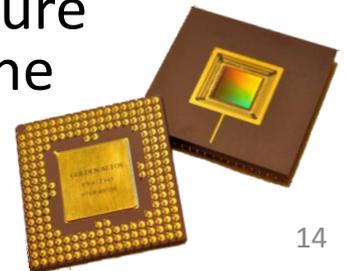


- Ceramic Components may be necessary for extreme temperatures such as -50 to $+125^{\circ}\text{C}$
 - Ceramic's coefficient of expansion is more stable
 - Useful for very large chips in extreme temperatures
 - the difference in cost between plastic and ceramic packages increases exponentially as pin counts rise



Ceramic vs. Plastic Details

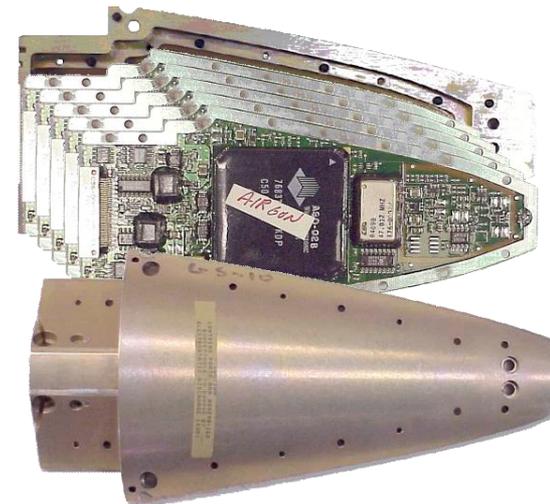
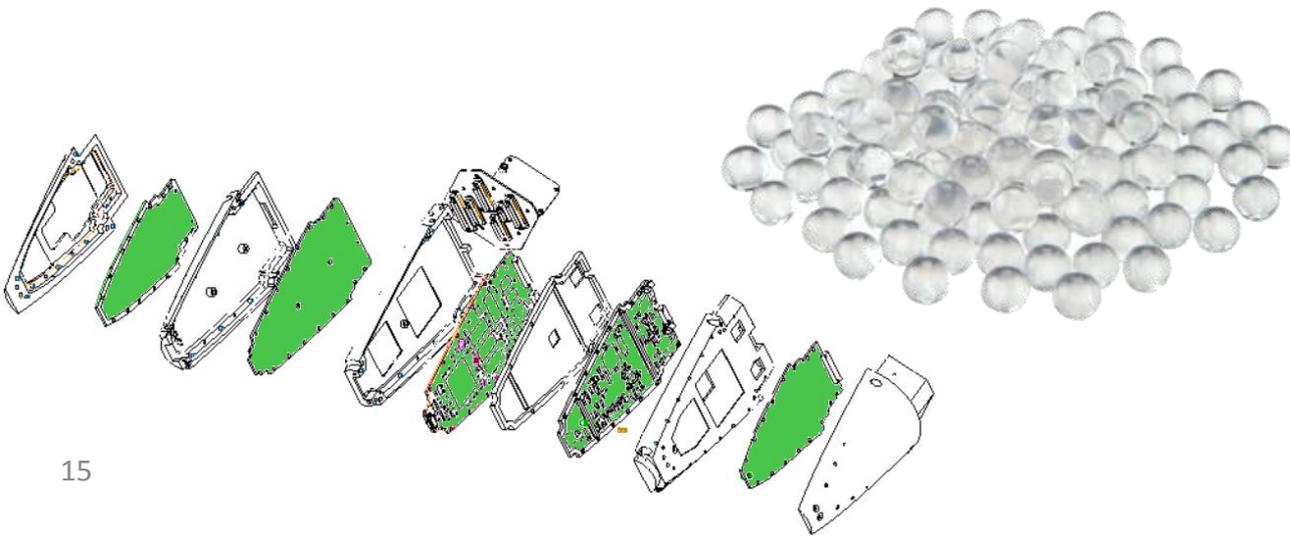
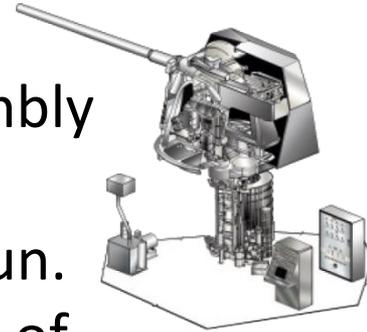
- Process developments in plastic components have resulted in high-reliability packages that meet the physical demands of most commercial, aerospace, and military equipment.
- The plastic chip is created by coating the silicon die with a polyimide film before the die is molded to the plastic.
- This polyimide film fills in the imperfections on the die's surface, creating a planar surface on which the plastic can expand and contract without damage.
- The polyimide itself has a thermal coefficient of expansion close enough to silicon that it poses no issues.
- *Eventually, this polyimide coating breaks down after several thousand temperature cycles.*
- A ceramic chip can withstand so many more temperature cycles that the ceramic chip's lifetime will far outlast the lifetime of the rest of the circuit board.





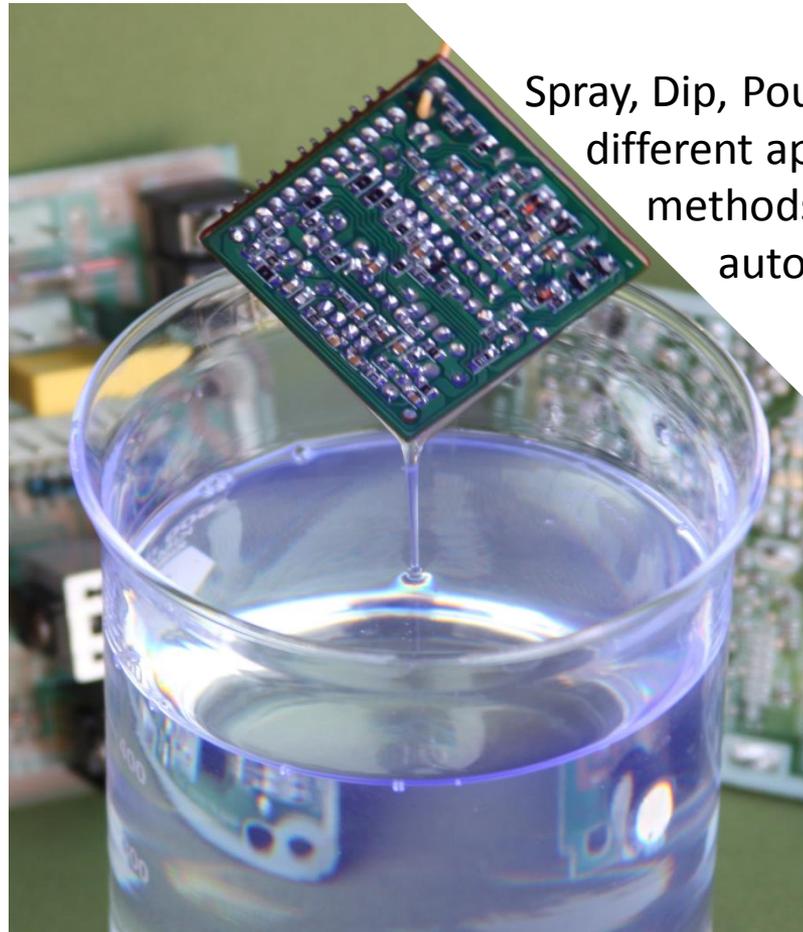
Glass Beads

- Glass Beads have been used to fill spaces between board layers in extremely high shock environments.
- The small beads are filled into the voids and the assembly vibrated to settle everything into place.
- ERGM was fired from the 5-inch 62-Caliber Mark 45 gun.
- ERGM was cancelled in March 2008 after twelve years of development due to (among many other issues) the electronic components not surviving the stress of being shot from a gun.

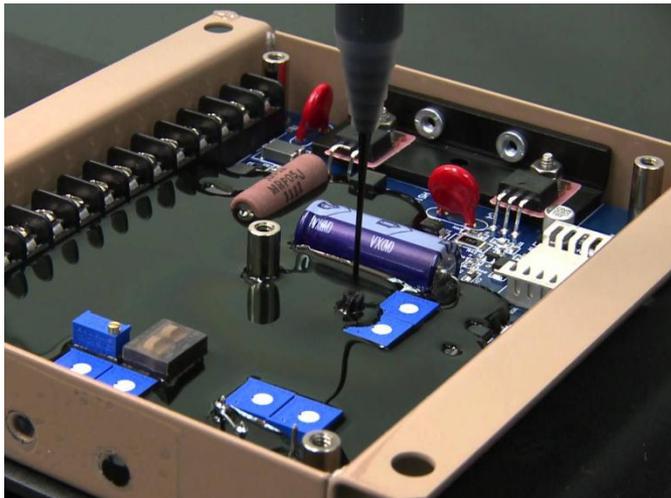


Conformal Coating

- Conformal Coating is like a rubber handle on a hammer
- Protects against humidity and corrosive contaminants such as salt-spray
- May help contain tin whisker growth if properly applied with appropriate material

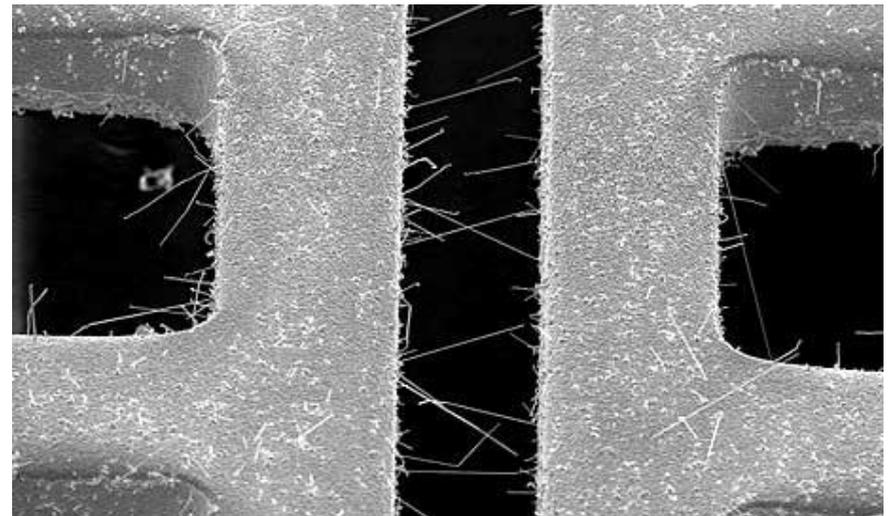
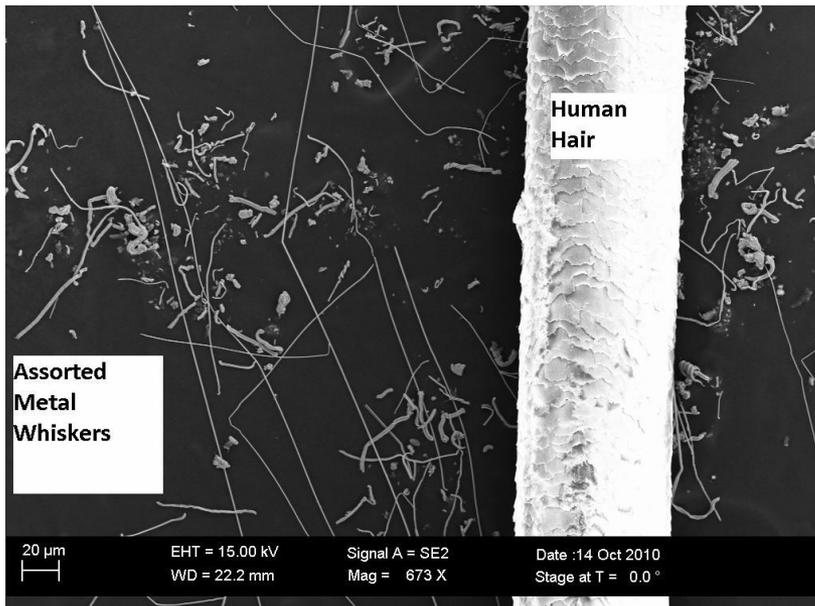


Spray, Dip, Pour. Many different application methods. Most done with automated equipment



Why does a board “break” over time?

- Most board failures will be physical.
- Expansion and contraction from heating and cooling cycles will cause fatigue like bending a paperclip over and over until leads break or cracks form.
- There’s also a phenomenon called Tin Whiskers
 - This is when environmental effects cause growth of whiskers from the solder joints ultimately causing shorting issues within the circuitry
 - Many papers and studies have made various conclusions
 - In short, Conformal Coating helps contain the whiskers (AARGM board is Conformal Coated)
 - As of 2015, NASA has been monitoring various samples for over 12 years with whiskers always an issue. Penetration of the coatings is mitigated using different applications and materials



Cost effects of Ruggedization

- There are many combinations of rugged values that affect boards and systems
- Shown below are five levels of ruggedization
 - Level-1 assumes no ruggedization
 - Levels 2-5 are common ruggedization levels sold by COTS vendors
 - Specific platforms have unique requirements and should be modeled with these specifications
 - The sample values below are for a system estimate with all items aggregated at the total level
 - Values modeled using PACER
- Rugged values coupled with Board specifics will determine the overall cost impact of Ruggedization at the system level.
- Below is an example of a unique combination of boards, enclosures, and backplanes that produces these cost differences.

Cost Effects of Ruggedization	Level-1	Level-2	Level-3	Level-4	Level-5
	\$ 100,000	\$ 133,821	\$ 168,993	\$ 213,846	\$ 257,425
Level-1 as Baseline	x 1.00	x 1.34	x 1.69	x 2.14	x 2.57
Level-2 as Baseline		x 1.00	x 1.26	x 1.60	x 1.92
Level-3 as Baseline			x 1.00	x 1.27	x 1.52
Level-4 as Baseline				x 1.00	x 1.20

