

CubeSat Thermal Testbed (CTTB)

Standoff Design for Enhanced Heat Transfer

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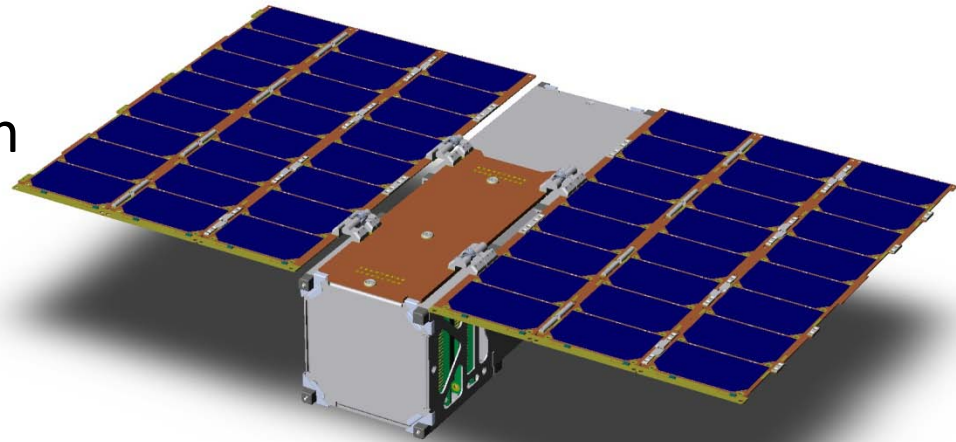
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Impetus for Research

Pumpkin delivered a CubeSat Thermal Testbed (CTTB) to JPL in Q3 2012. The CTTB has dual 24W solar arrays feeding independent 46W dc/dc converters. These particular dc/dc converters work surprisingly well in vacuum, and prompted us to investigate how to improve CubeSat structural design for higher power levels ...



CubeSat Thermal Testbed CAD model

Motivation

- Known thermal issues regarding transmitter power. Additionally, CubeSat power systems are trending towards higher power levels
- Reduce the amount of additional mass needed for an effective thermal dissipation system by using existing large thermal mass (ADACS)
- Design a passive thermal subsystem
- MISC™ 2 / Colony I utilized standard CubeSat Kit™ module stacking hardware – non-optimized thermal transfer between modules, little access to large thermal masses
- MISC™ 3 arranges high thermal output components near the thermal mass, opportunity to improve inter-module thermal transfer and increase payload volume



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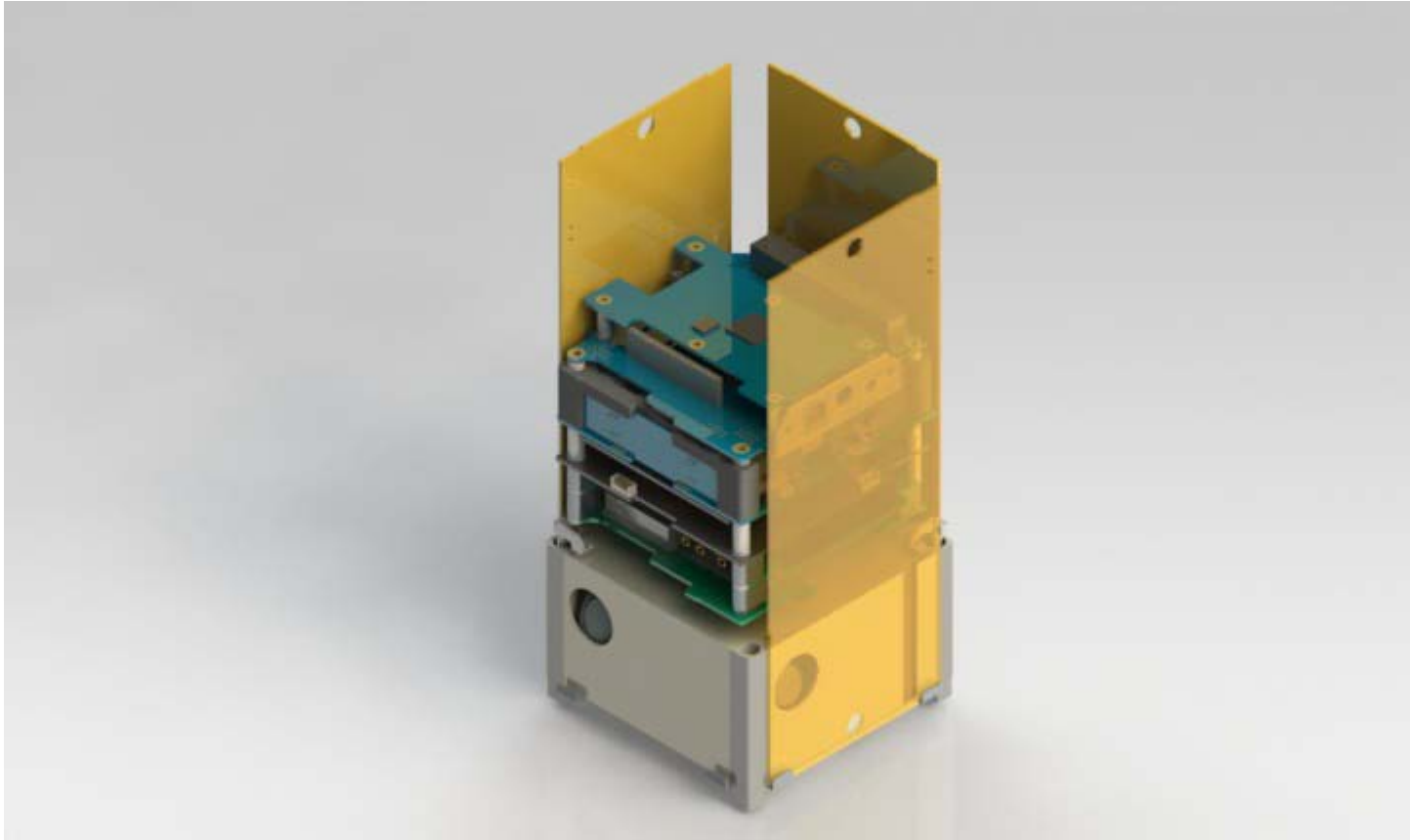
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MISC 3 Stack-Up



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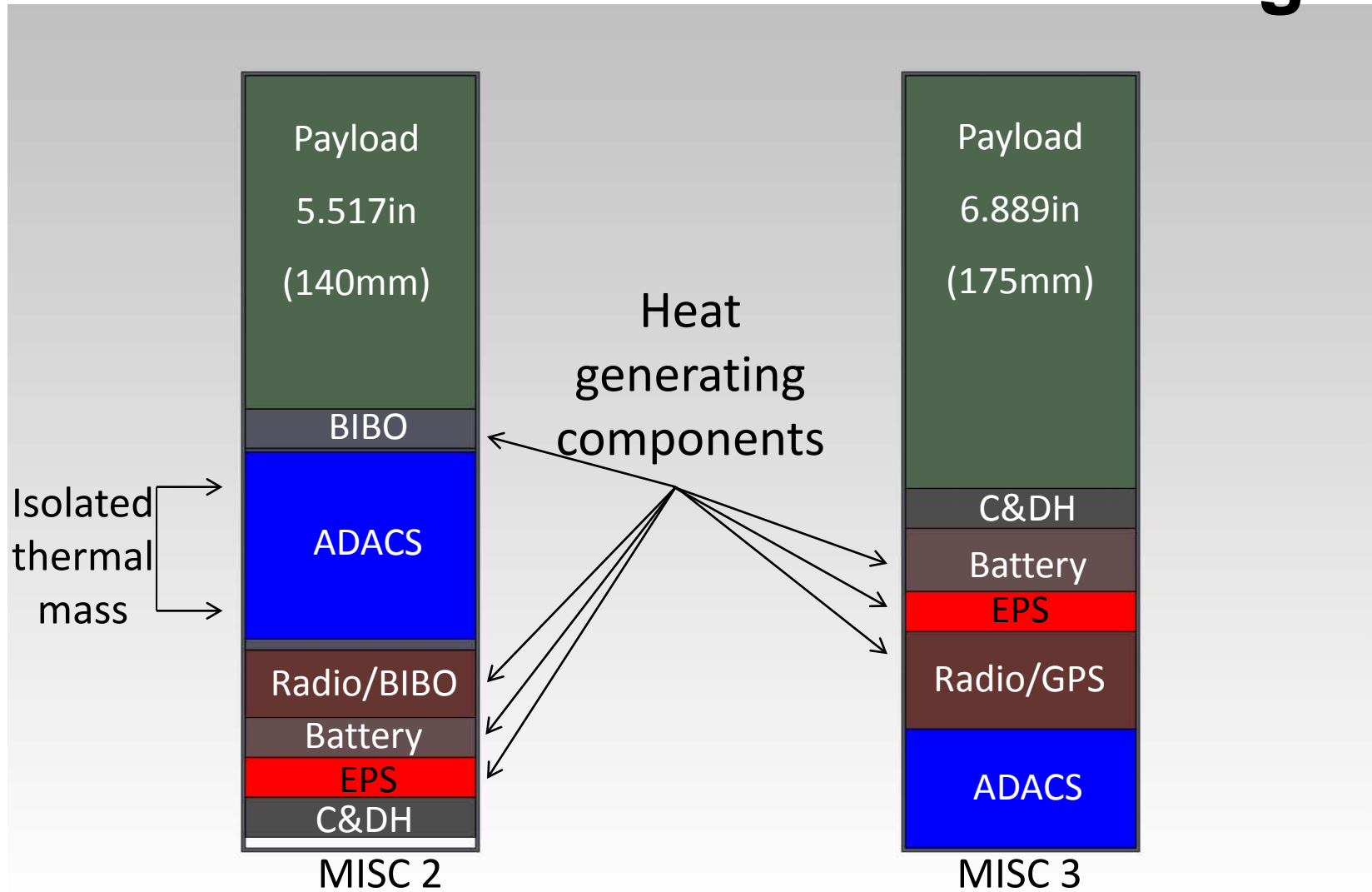
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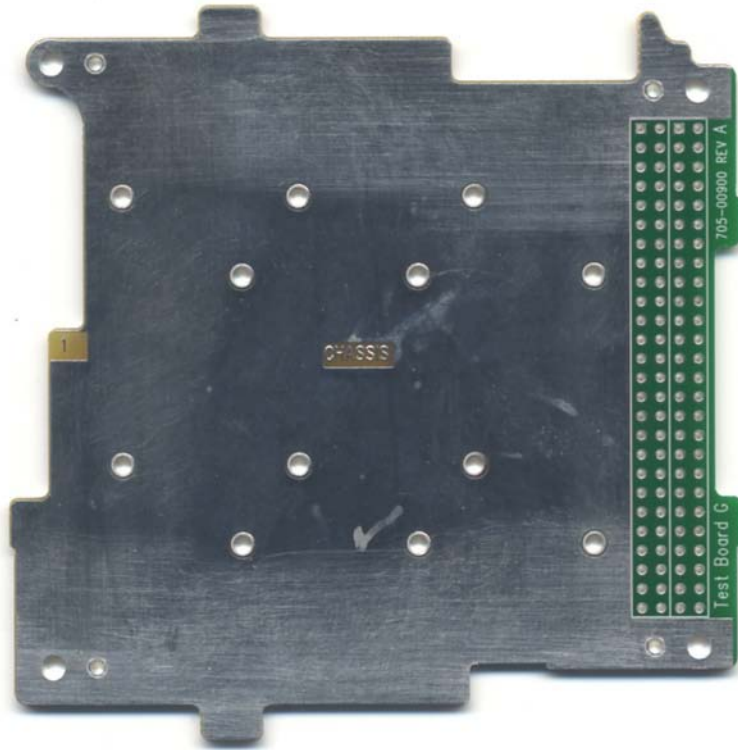
MISC 2 vs MISC 3: Module Stacking



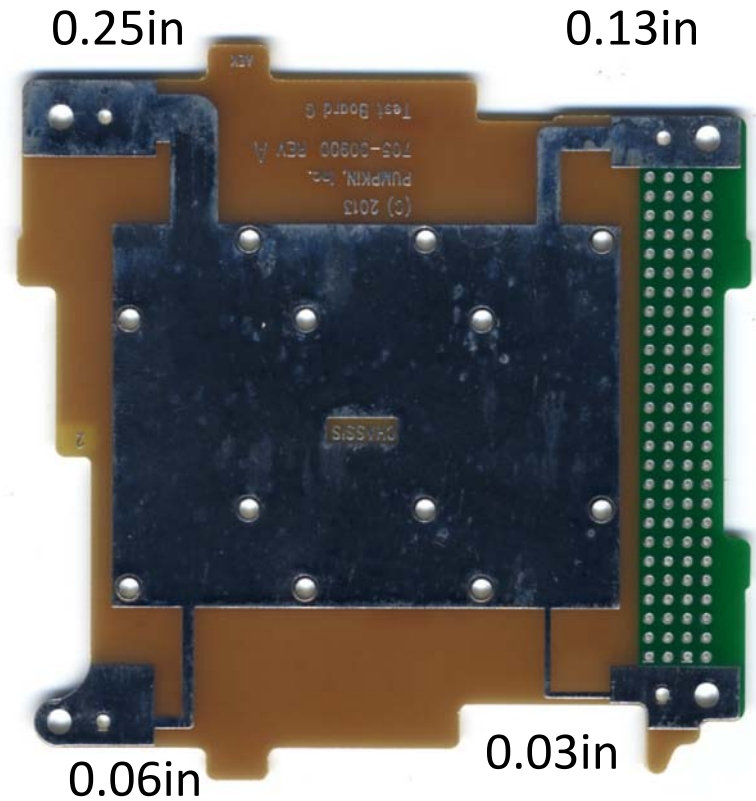
The Idea

- Focus on utilizing existing features within a CubeSat Kit for thermal dissipation (Discrete heat pipes and large heat sinks are desirable, but mass and volume budgets do not always allow for them)
- Within MISC, ADACS is the single largest mass
- “Move” heat from heat generating elements toward the larger thermal mass
 - Use a new design for standoffs to move heat between boards
 - Use copper traces and floods on PCBs for local heat transfer

Test Board

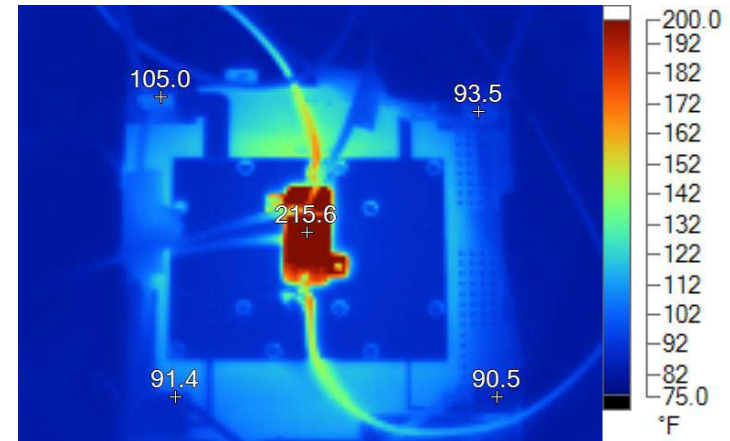
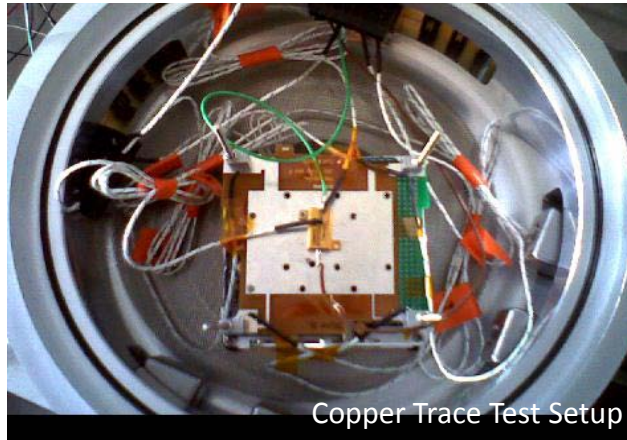


For Standoff Comparison Test

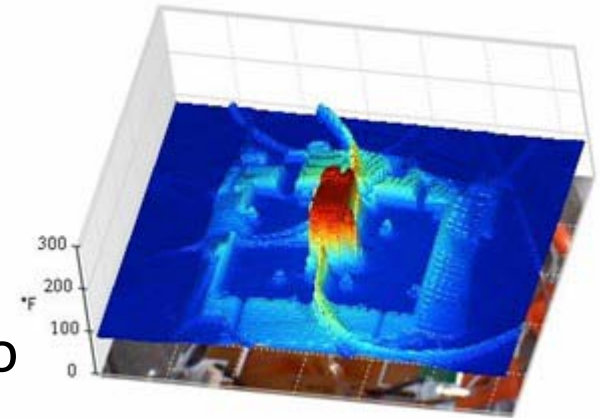


For Copper Trace Test

Local Heat Transfer in Ambient Air

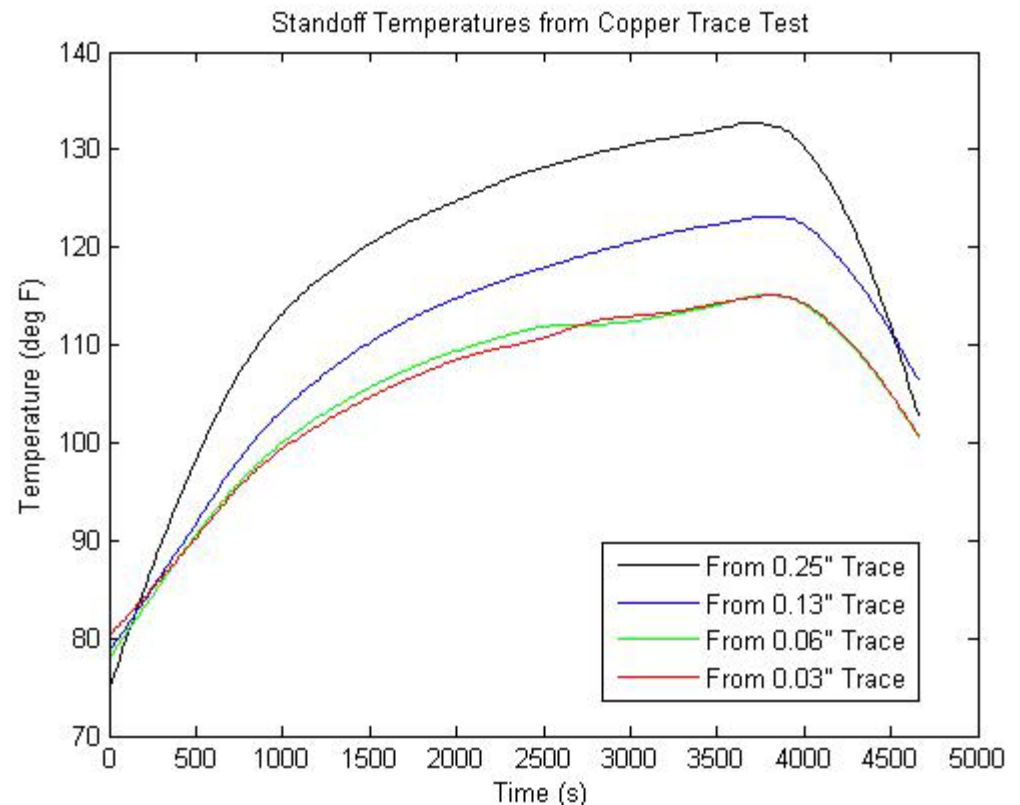


- Infrared image of test fixture in ambient air after 20 minutes of 5W of power to the resistor
- Copper floods maintain much lower temperatures than PCB fiberglass
- Trace thickness does increase heat transfer to standoffs, allowing for a local method of transporting heat



Local Heat Transfer In Vacuum

- Same trend as seen during ambient air test
- Resistors ran for approximately one hour before shutting off, allowing to observe cool-down trend



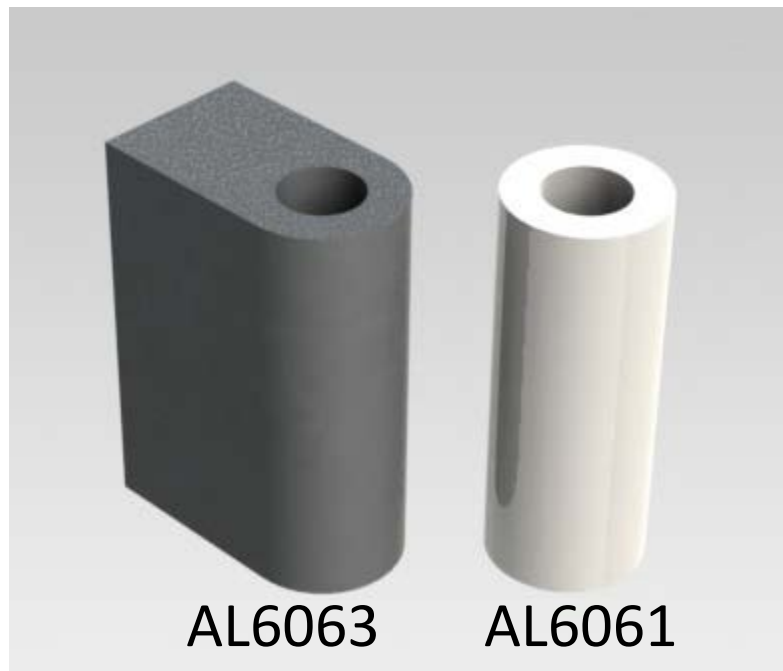
Conclusion: Larger PCB traces increase heat transport while heating up as well as cooling down allowing for local heat transport on the PCB board

Thermal Standoff Material Selection

Material	Thermal Conductivity [W/mK]	Specific Heat [J/gC]	Density [kg/m ³]	Cost
Diamond	2000	0.508	3510	\$x10
Carbon Fiber	21-500	0.710	1360-2000	\$\$\$
Copper	385	0.375	8890	\$\$\$\$\$
SST 30X	16	0.500	8000	\$\$\$
Al 5052	138	0.880	2680	\$
Al 6063	209	0.900	2700	\$
Al 6061	167	0.896	2700	\$
Al 7075	130	0.960	2810	\$

Physical Differences

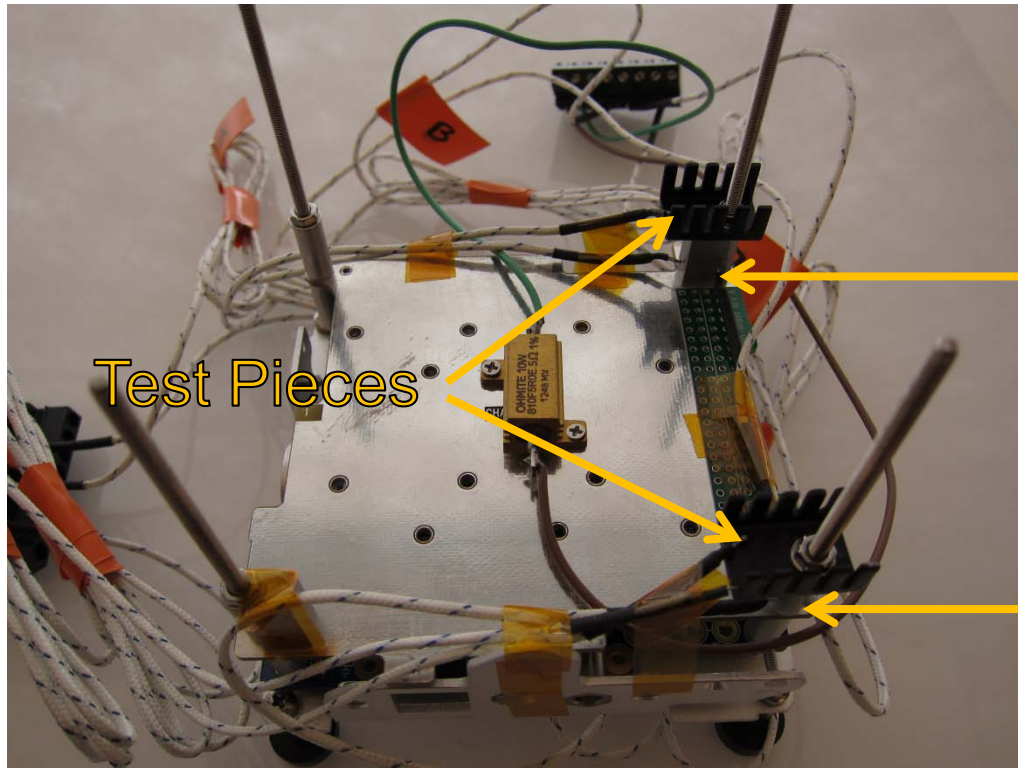
! Design Impact: this does take away board real estate near the corners



For 0.6" tall aluminum standoffs...

- 162% additional mass
- 65% additional exposed surface area to radiate
- 161% additional contact surface area for conduction

Standoff Comparison Test Setup



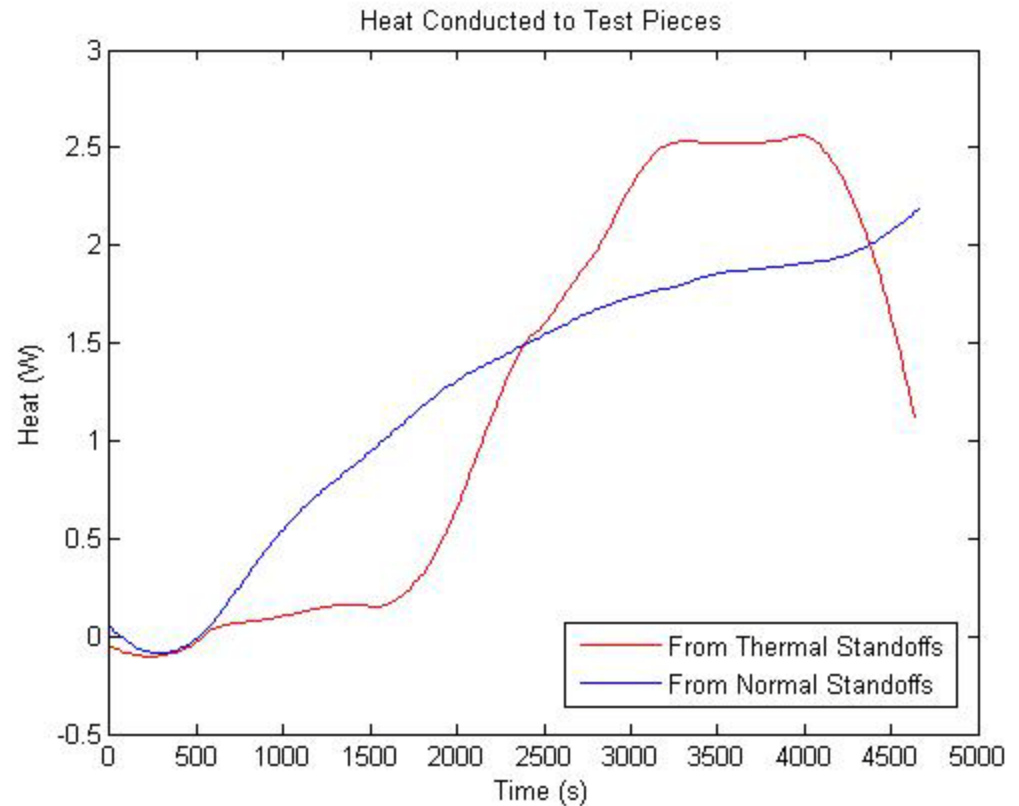
Thermal Standoff

Normal Standoff

Test Pieces

Standoff Comparison in Vacuum

- 5W of power to resistor for approximately one hour, then turned off resistor to observe cool-down trend
- Thermal standoff's low heat conduction during the beginning of the test is reflective of higher heat capacity



Conclusion: Thermal standoff does conduct more heat to respective test piece allowing for heat transfer within a CubeSat Kit stack

Aid of finishes

- Radiation can be radically affected by the type of finish
- Anodizing
 - Aluminum oxide finish
 - Excellent emissivity
 - Very tough finish and low cost
 - Electrically non-conductive
 - Colors are dyed in (black and clear are standard)
 - RoHS compliant

Unfinished aluminum has an emissivity < 0.2

Black anodized aluminum has an emissivity ~ 0.82

Ongoing Research and Future Tests

- Incorporating direct connection to thermal mass and testing
- Variable power tests
- Testing with surface treatments
- Effect of thermal interfaces
 - Pressure sensitive adhesives (PSA)
 - Thermal pads
 - Epoxy
 - Grease
- Test using actual CubeSat components, i.e. radio, EPS, etc.



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Appendix

• Speaker information

- Jerami Martin is a Systems Engineer at Pumpkin. She received her Bachelors of Science in Aerospace Engineering from University of California, San Diego and her Masters of Science in Aeronautics & Astronautics from Stanford University. Contact Jerami at [jerami @ pumpkininc.com](mailto:jerami@pumpkininc.com).

• Acknowledgements

- Pumpkin's Salvo, CubeSat Kit and MISC customers, whose real-world experience with our products helps us continually improve and innovate.

• CubeSat Kit information

- More information on Pumpkin's CubeSat Kit can be found at <http://www.cubesatkit.com/>. Patented and Patents pending.

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