CubeSat Thermal Testbed (CTTB)

Standoff Design for Enhanced Heat Transfer

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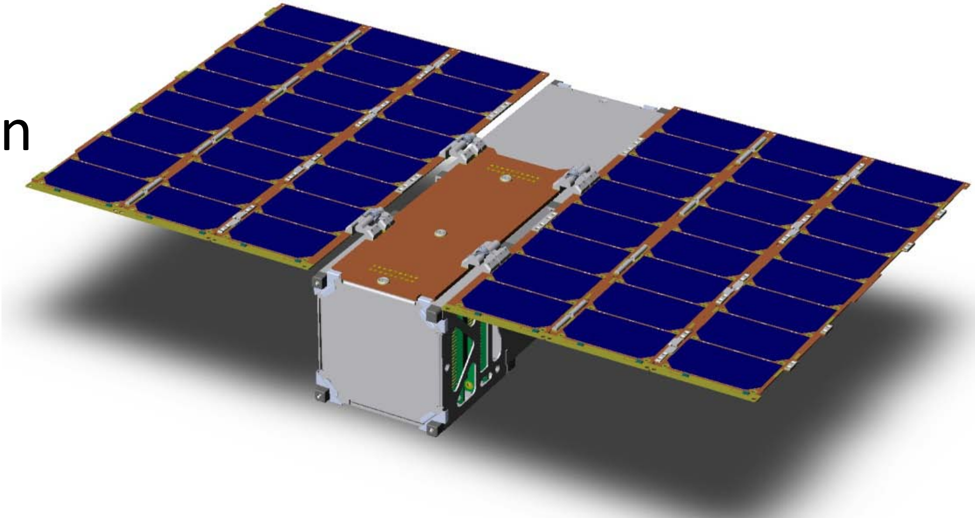
Impetus for Research

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 …

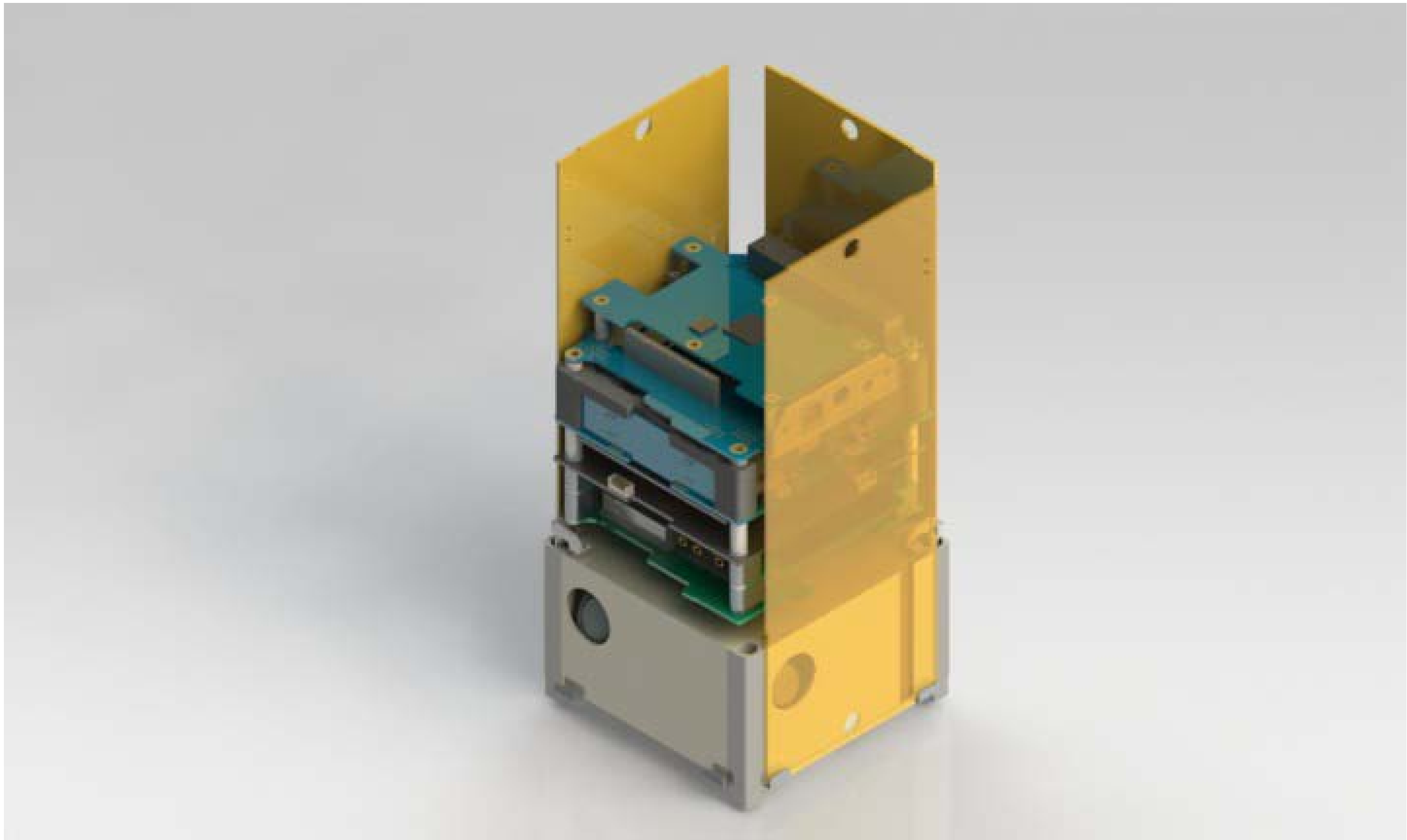


CubeSat Thermal Testbed CAD model

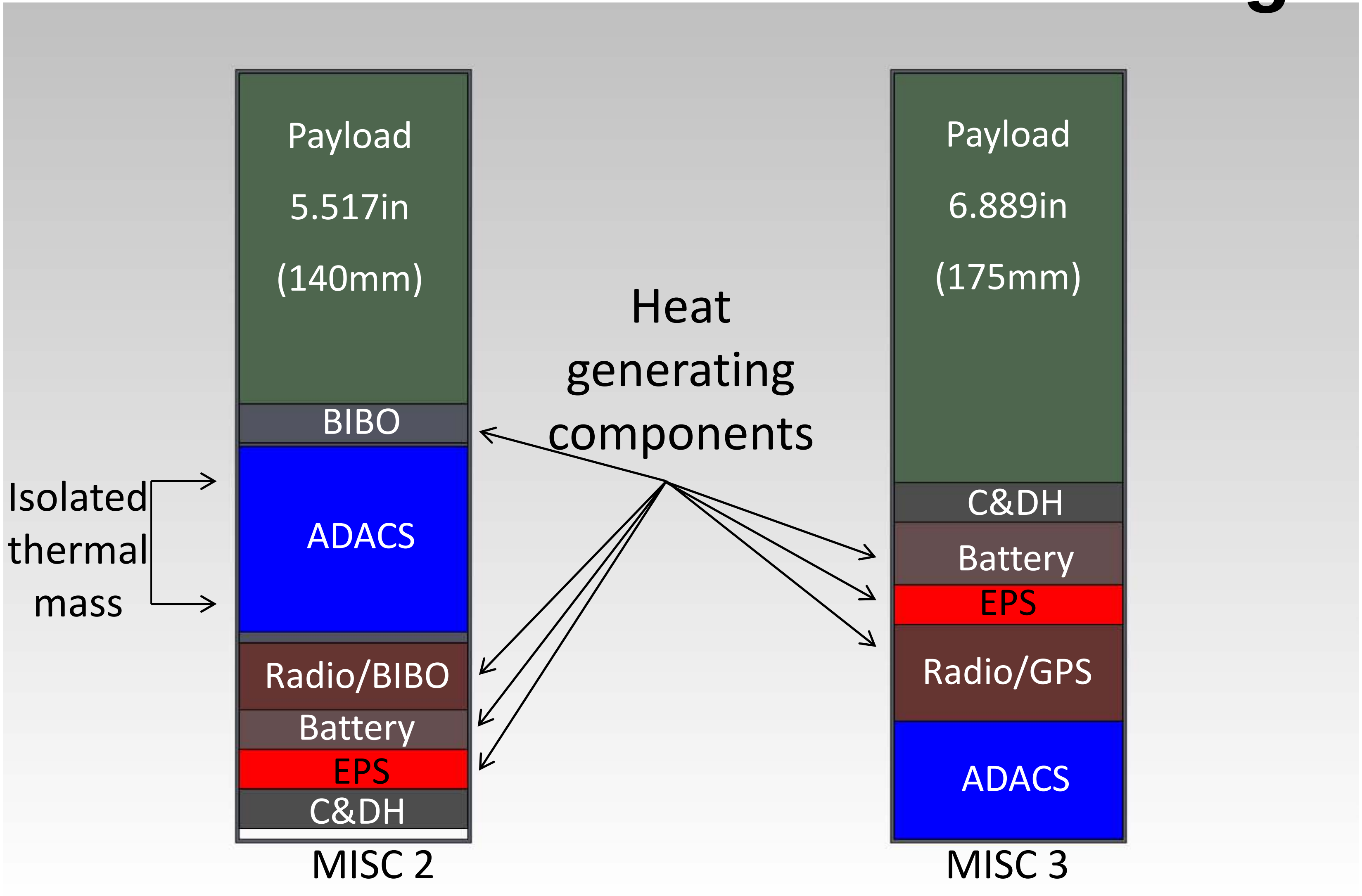
Motivation

- 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

MISC 3 Stack-Up



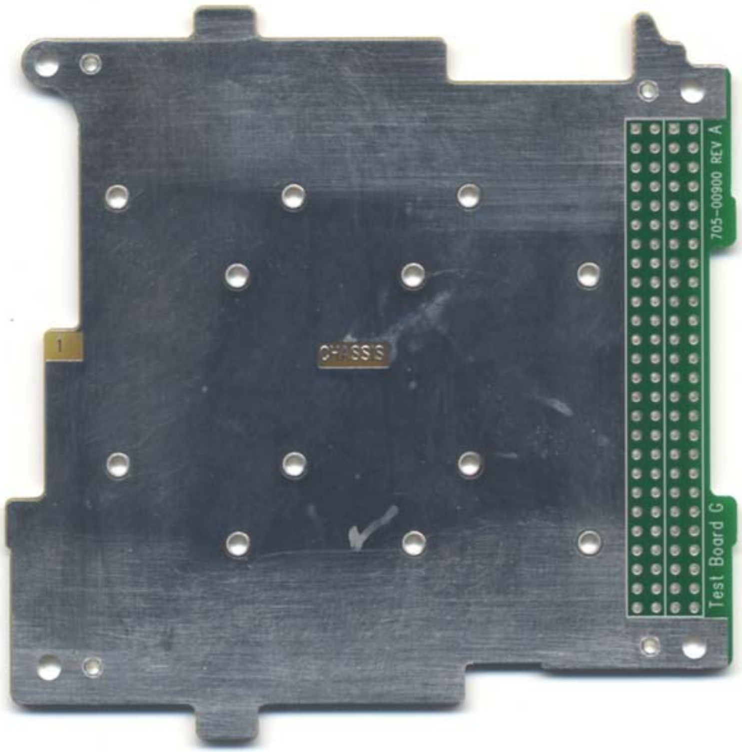
MISC 2 vs MISC 3: Module Stacking



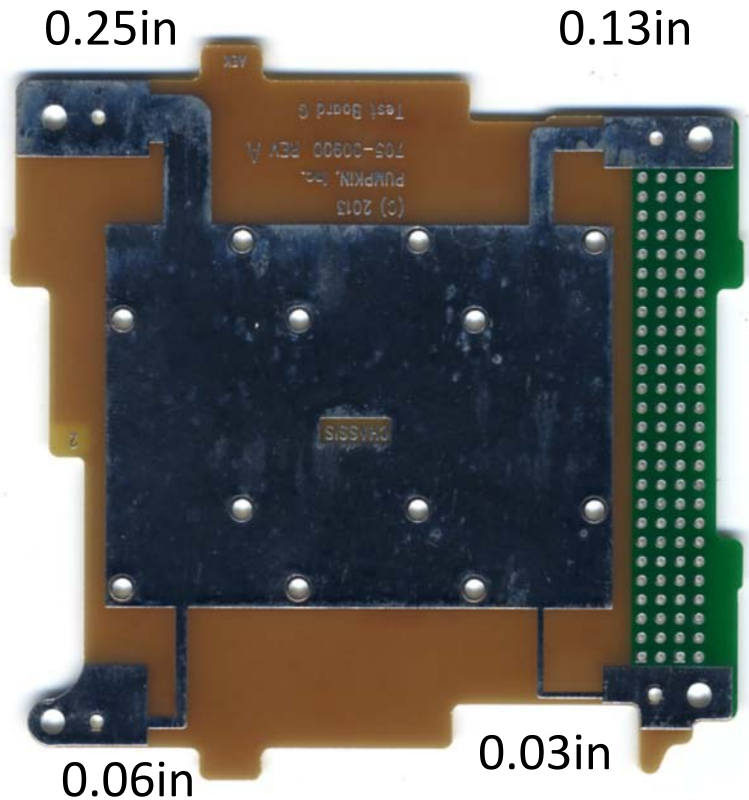
The Idea

- 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

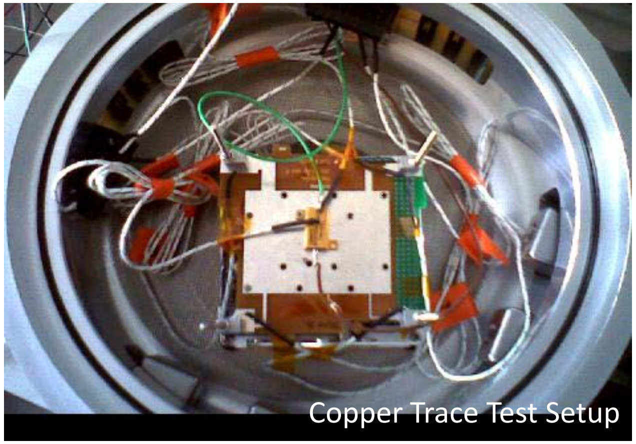


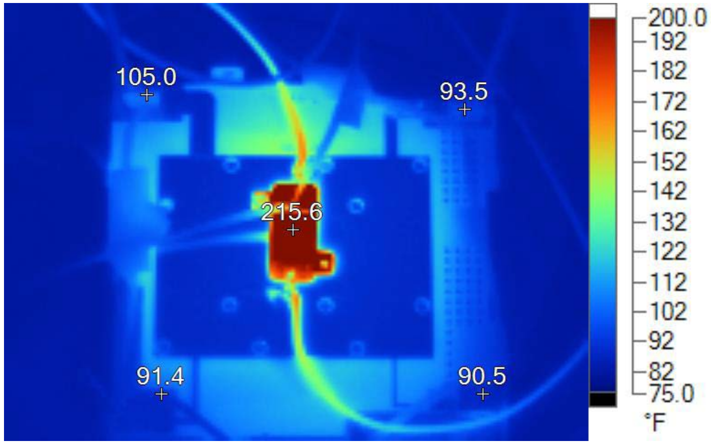
For Standoff Comparison Test



For Copper Trace Test

Local Heat Transfer in Ambient Air

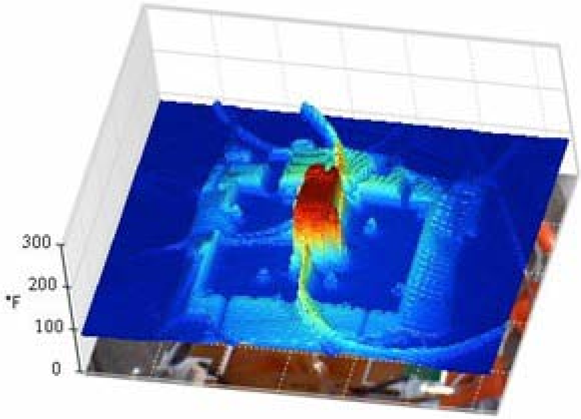

Copper Trace Test Setup



- Infrared image of test fixture in ambient air after 20 minutes of 5W of power to the resistor

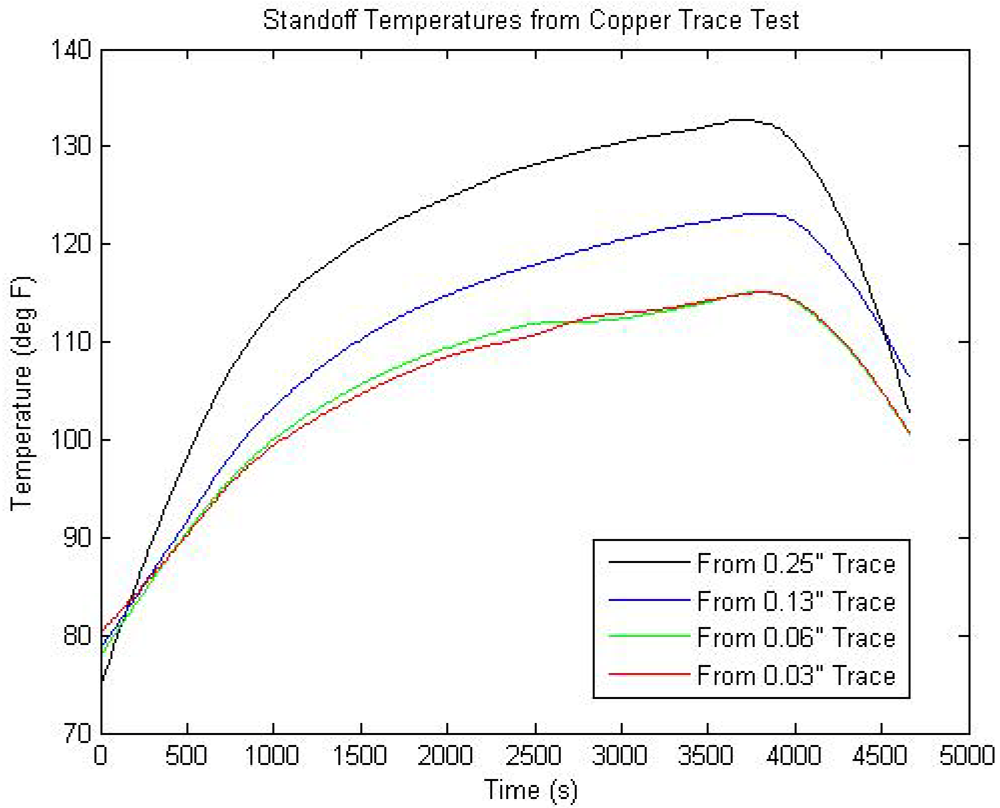
- Copper floods maintain much lower temperatures than PCB fiberglass

- 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



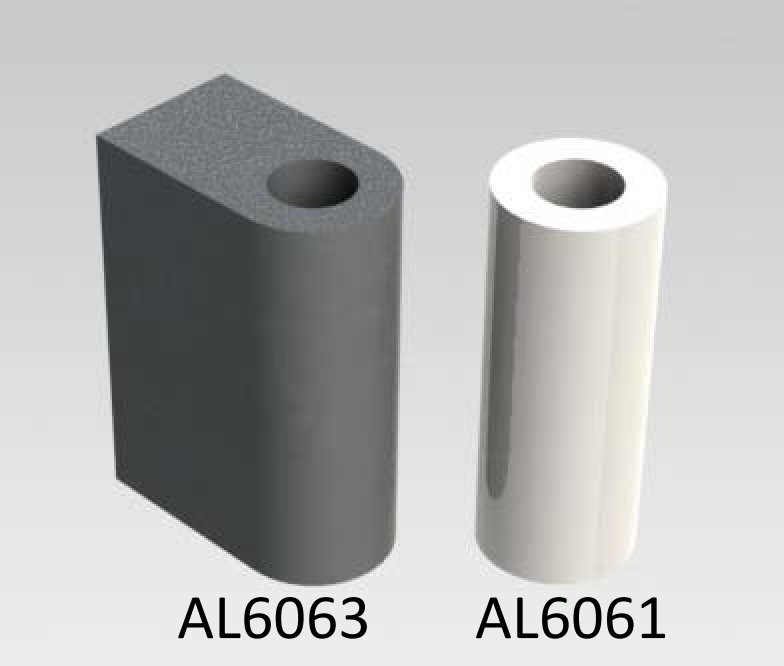
Conclusion: Larger PCB traces increase heat transport while heating up as well as cooling down allowing for local heat transport on the PCB board

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

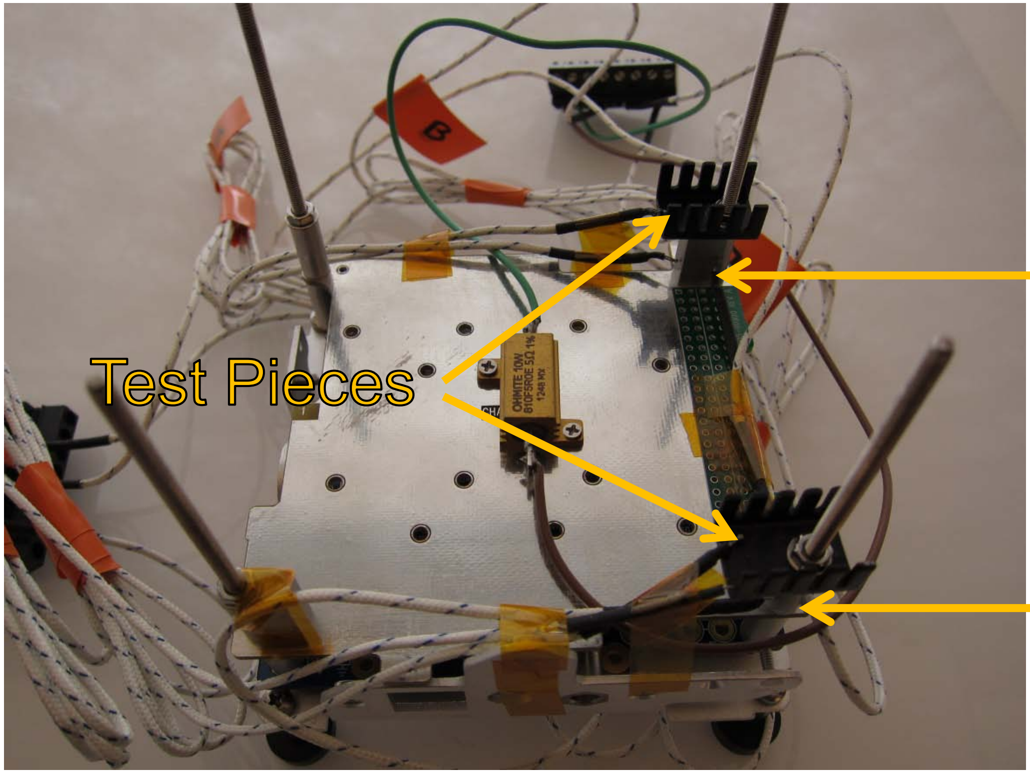
⚠ Design Impact: this does take away board real estate near the corners



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

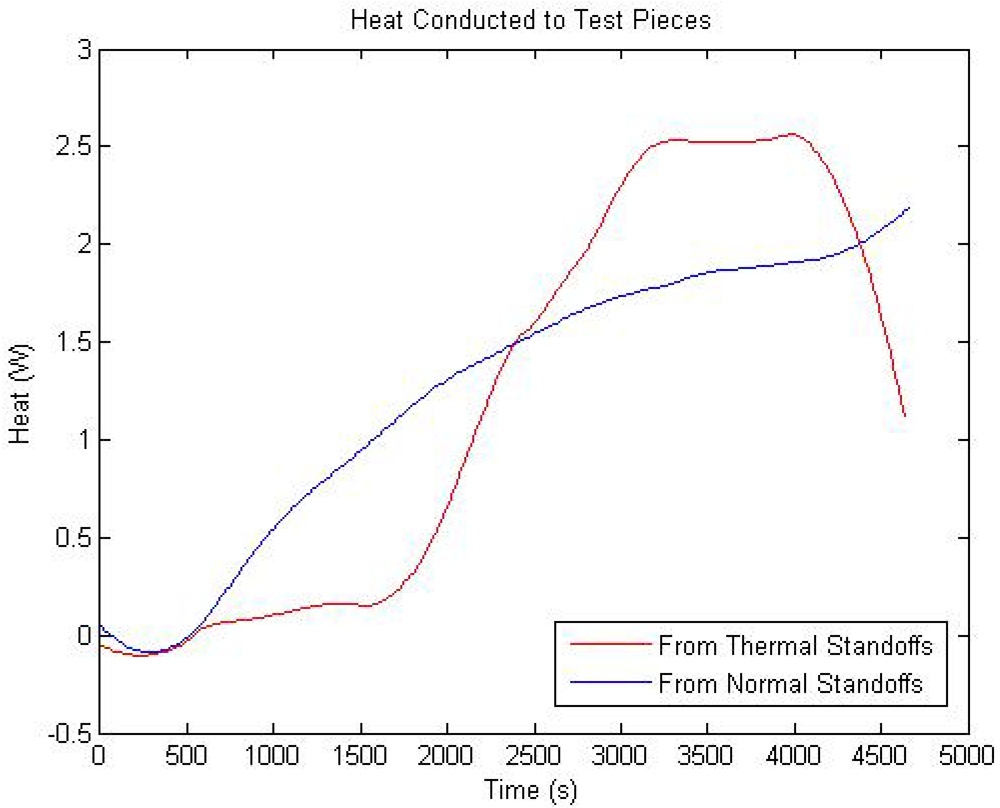


Thermal Standoff

Normal Standoff

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.

PUMPKIN™

SPACE SYSTEMS

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.

- 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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