Passively Deployed, Unfolding Radiator Panels for Small Satellite Thermal Management

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Motivation

- CubeSat Thermal Control
  - Large fluctuations in external and internal thermal loads
  - Small form factor
  - High power to surface area ratio
  - Strict temperature limits on control electronics and instruments

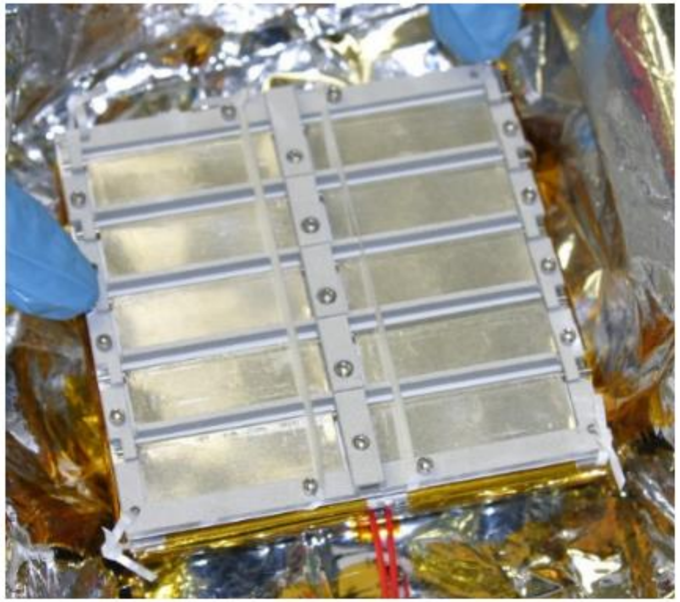
Is it powered?

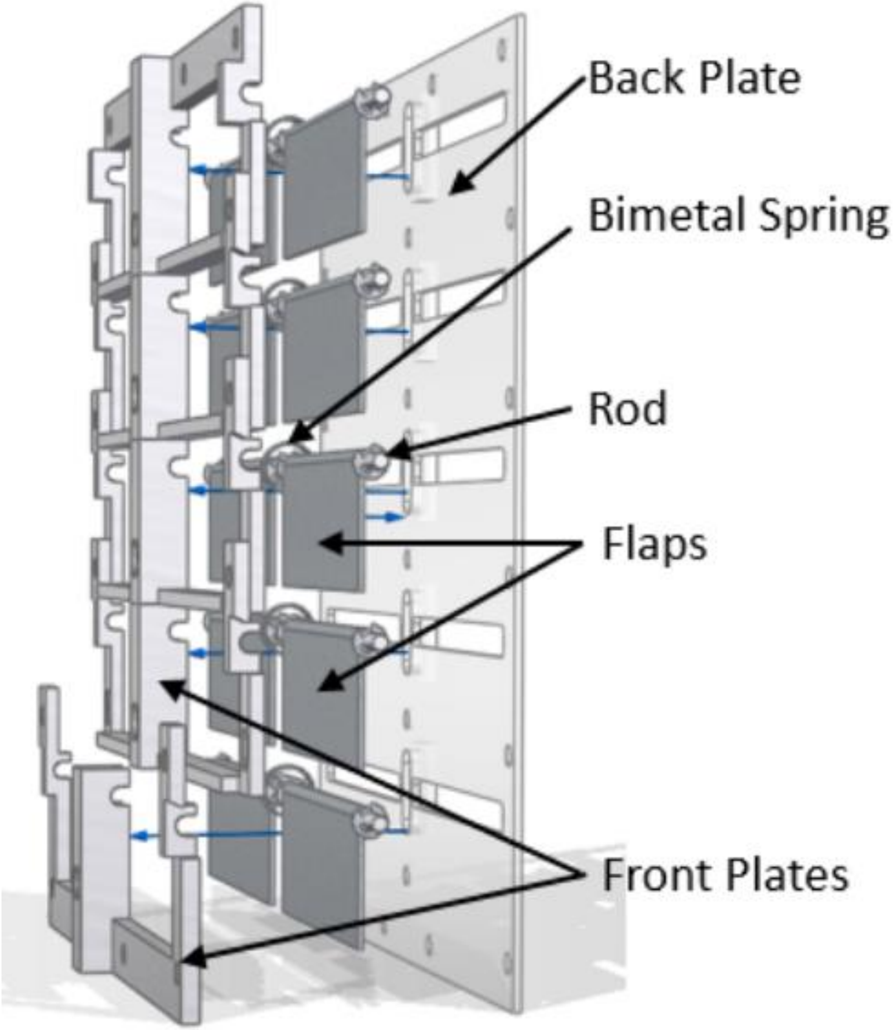
Is it responsive?

	Active	Passive
Static	**Cold-biased satellite with survival heaters**	**No thermal control system**
Dynamic	**Electrochromics**	**This work**

Similar Work - Louvers

- Louvers passively actuated by bimetal coils
- Flew on Dellingr CubeSat in 2018
- Limitations:
  - No significant increase in radiative surface area

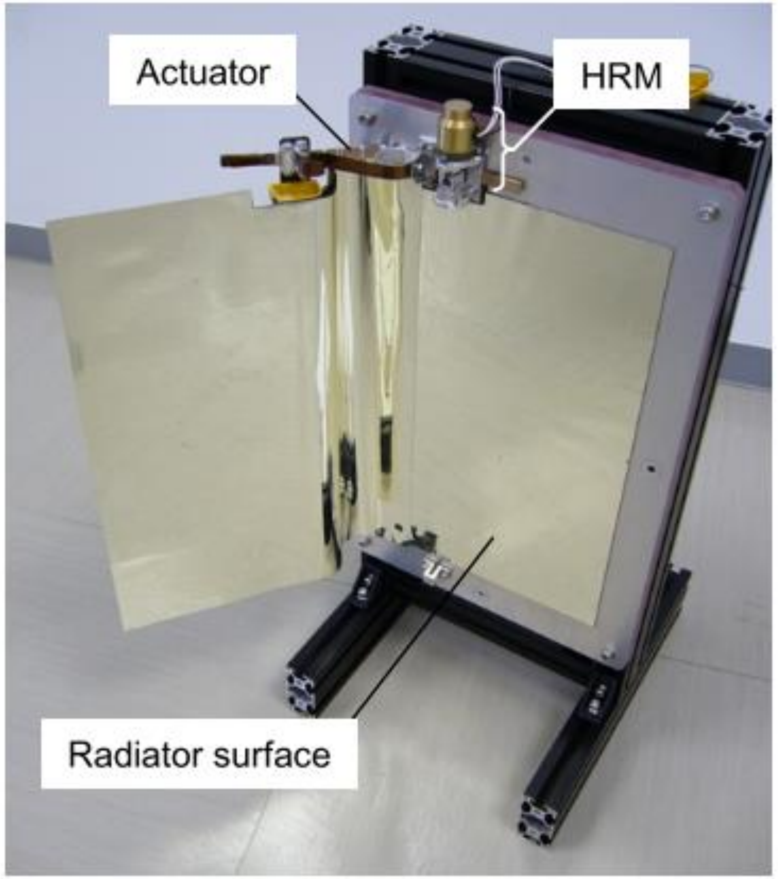


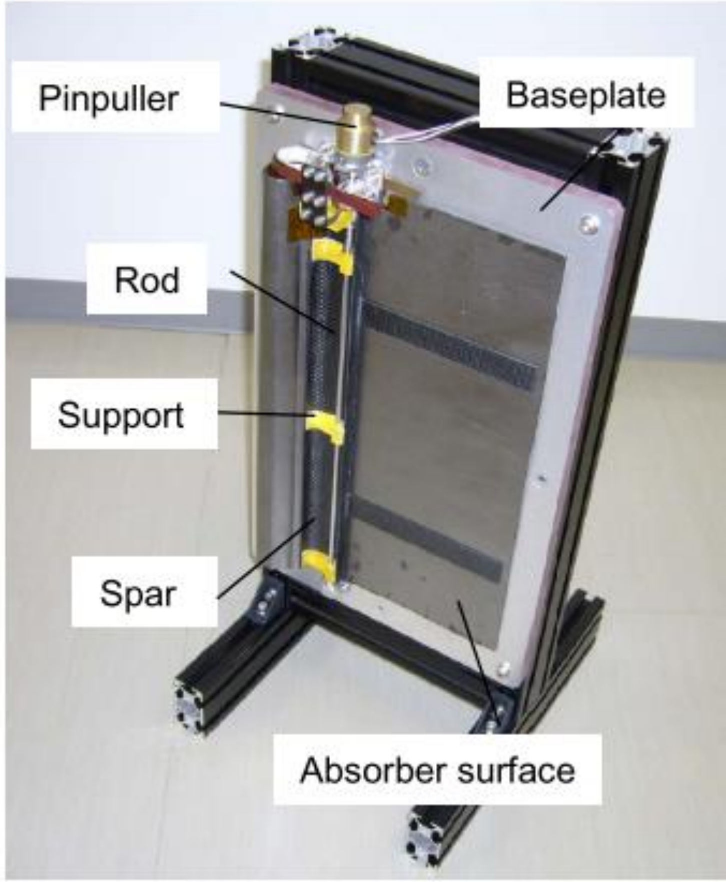


[1] Proceedings of AIAA, Evans 2019

Similar Work – SMA radiator

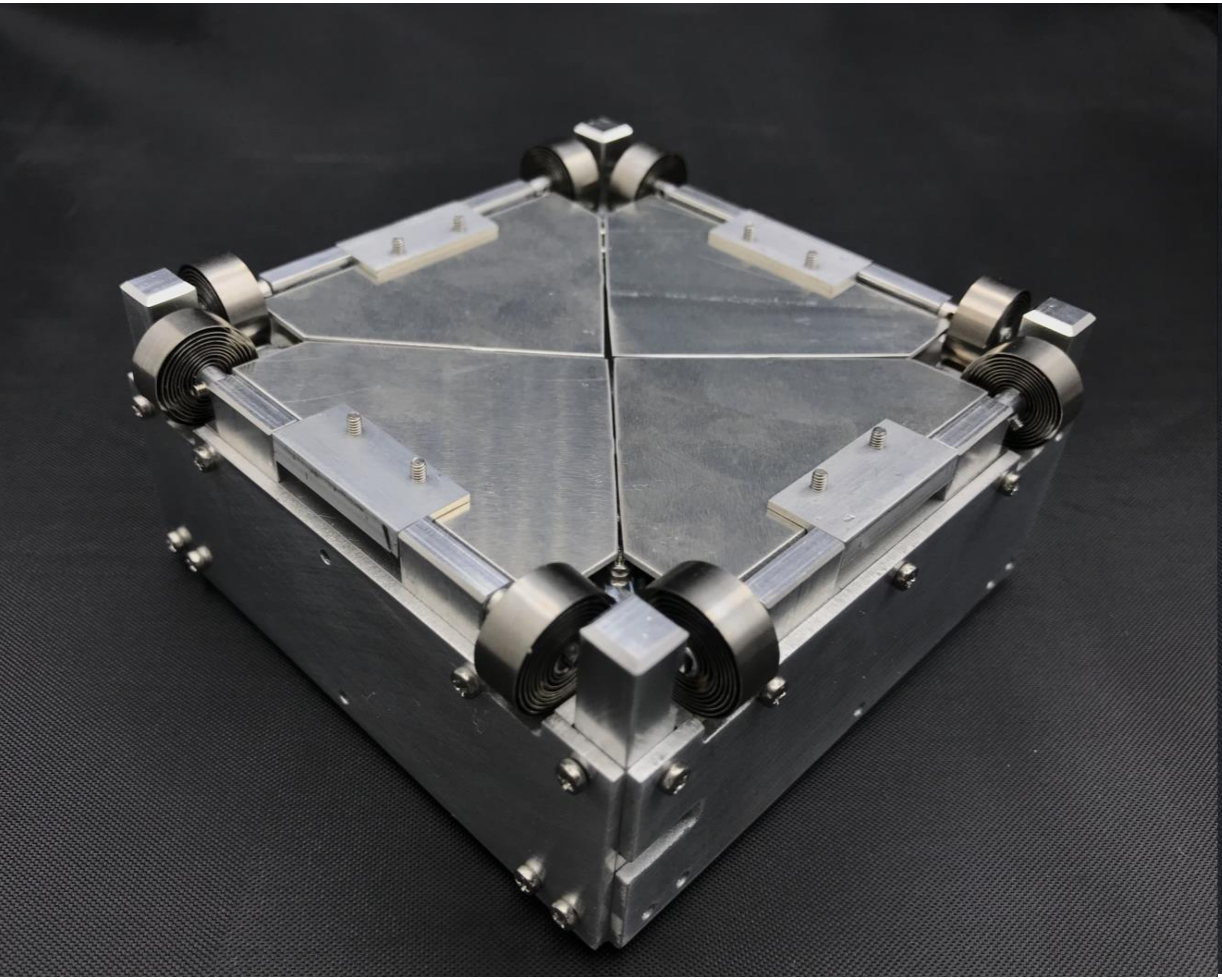
- Passively deployed radiator actuated by SMA
- Limitations:
  - Intermediate states not possible
  - Some hysteresis between stowage and deployment

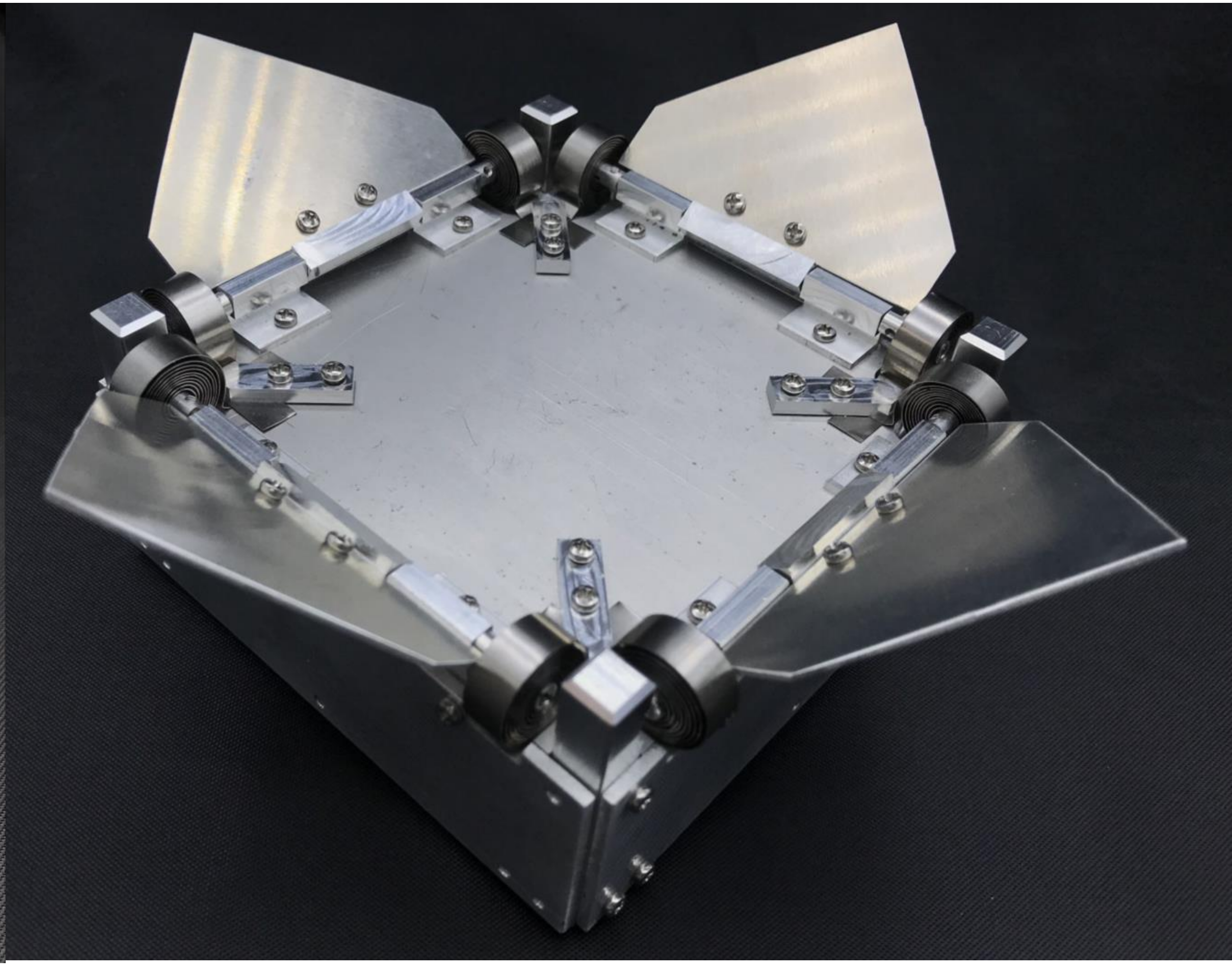




[2] JSR, Nagano 2009

Proposed Design





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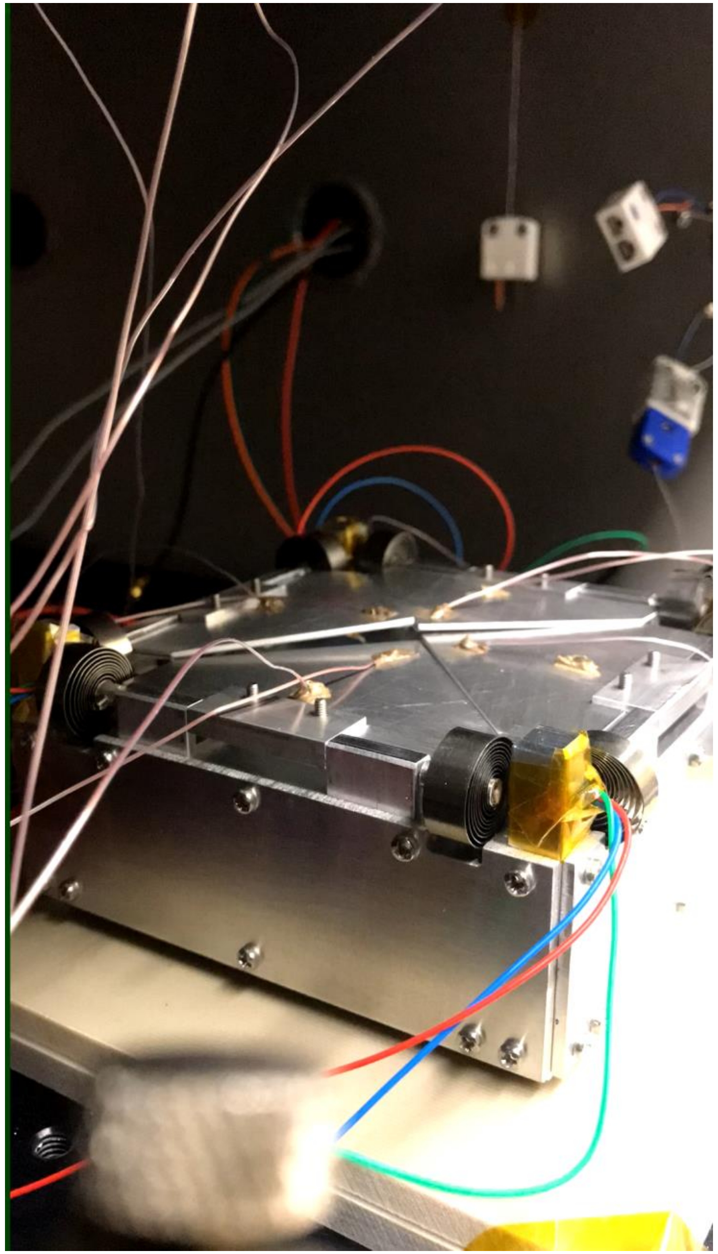
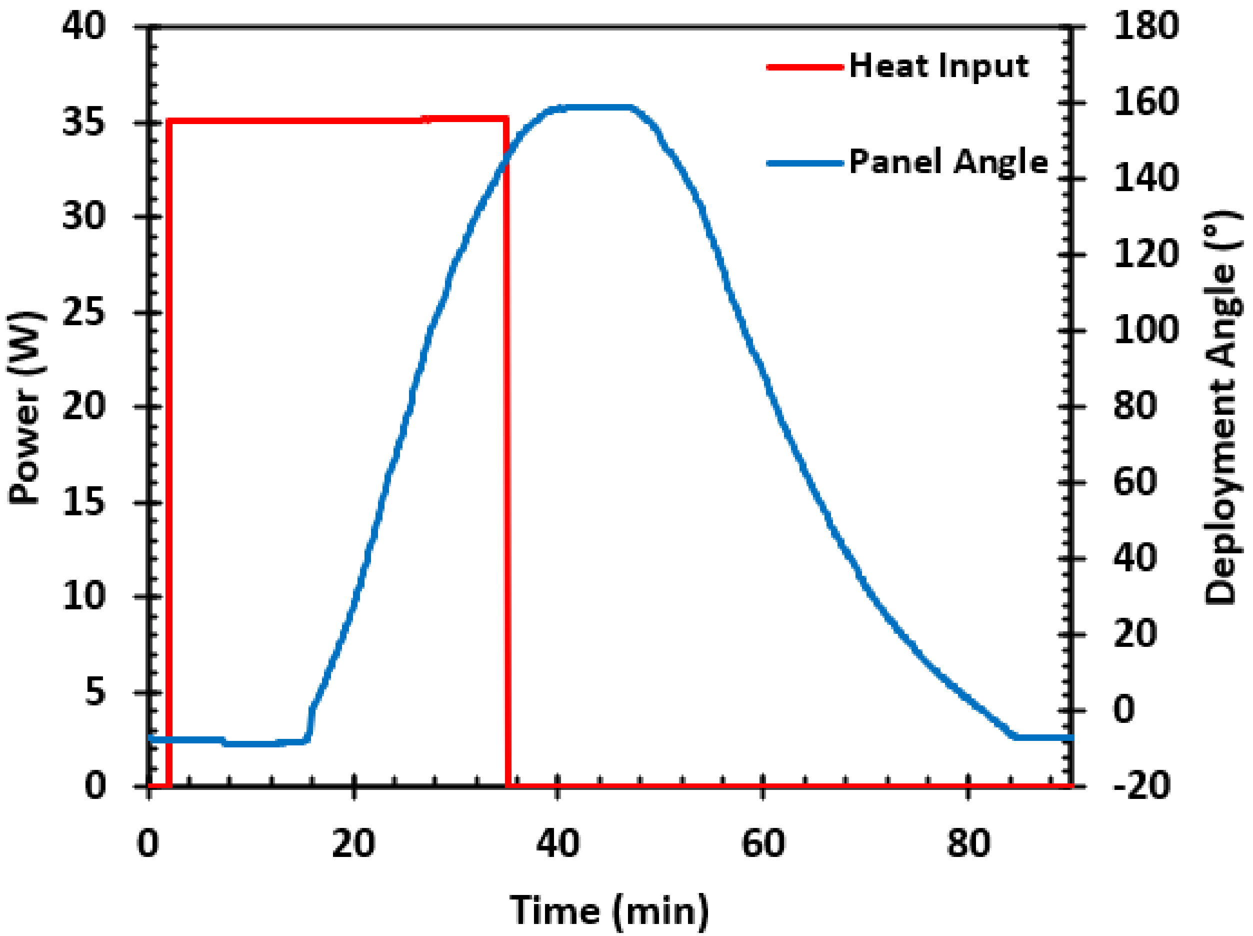
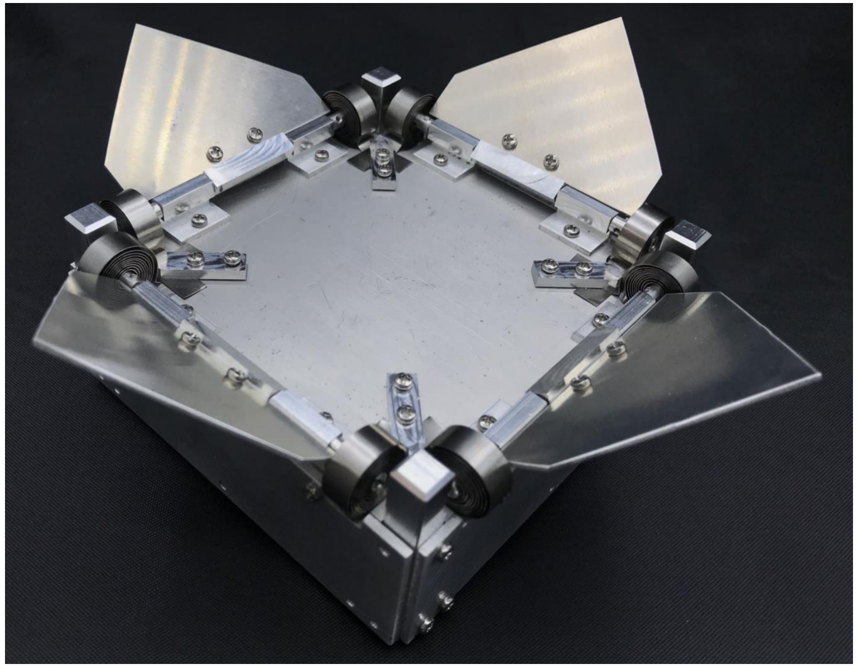


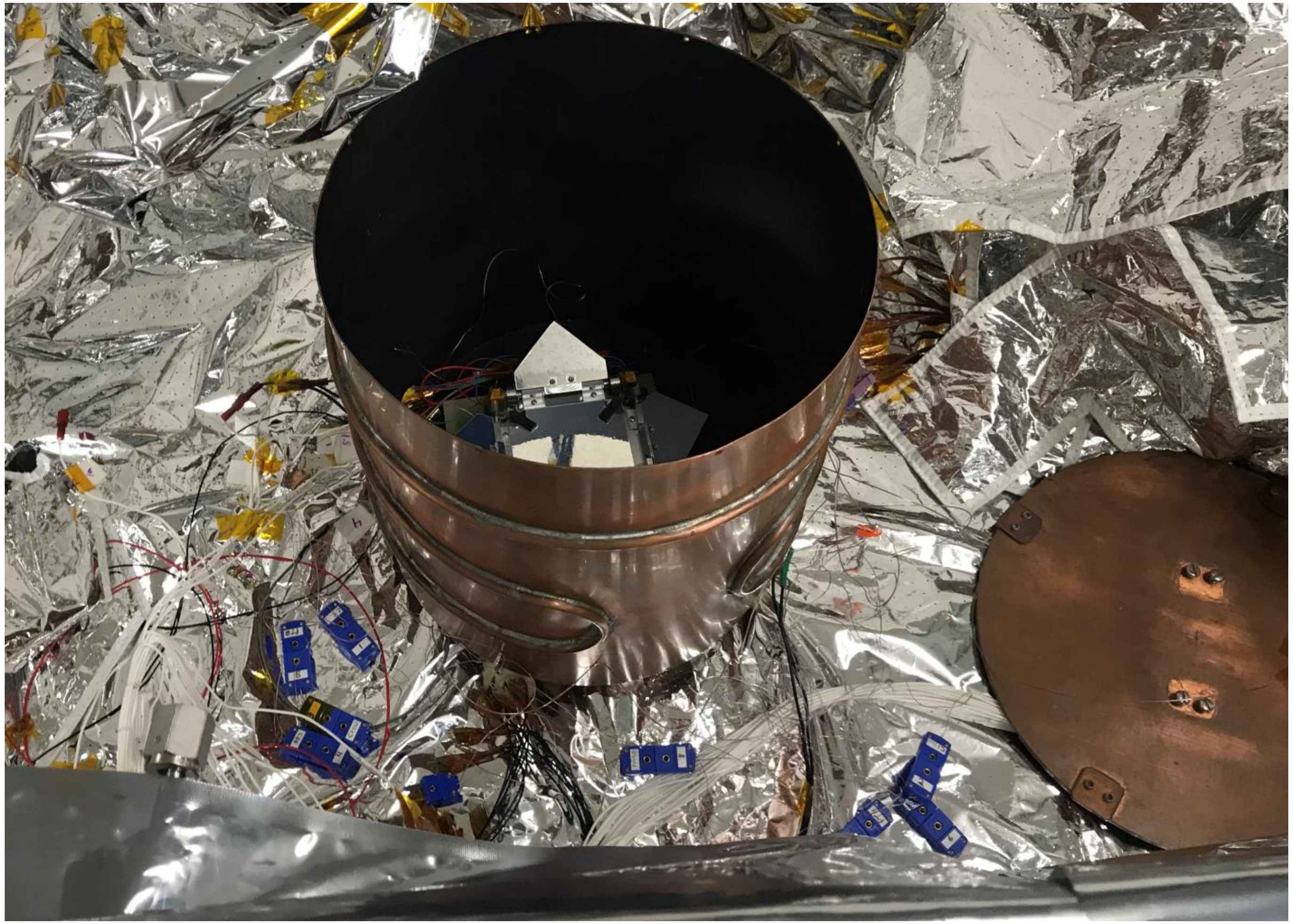


Advantages of Proposed Design

- Improved reliability and redundancy (4 panels rather than 1)
- Reduced complexity
- Potential for high turndown ratio and maximum heat loss
- Minimal hysteresis
- Intermediate steady state positions achievable
- Completely external to CubeSat body



Vacuum Chamber Test Setup



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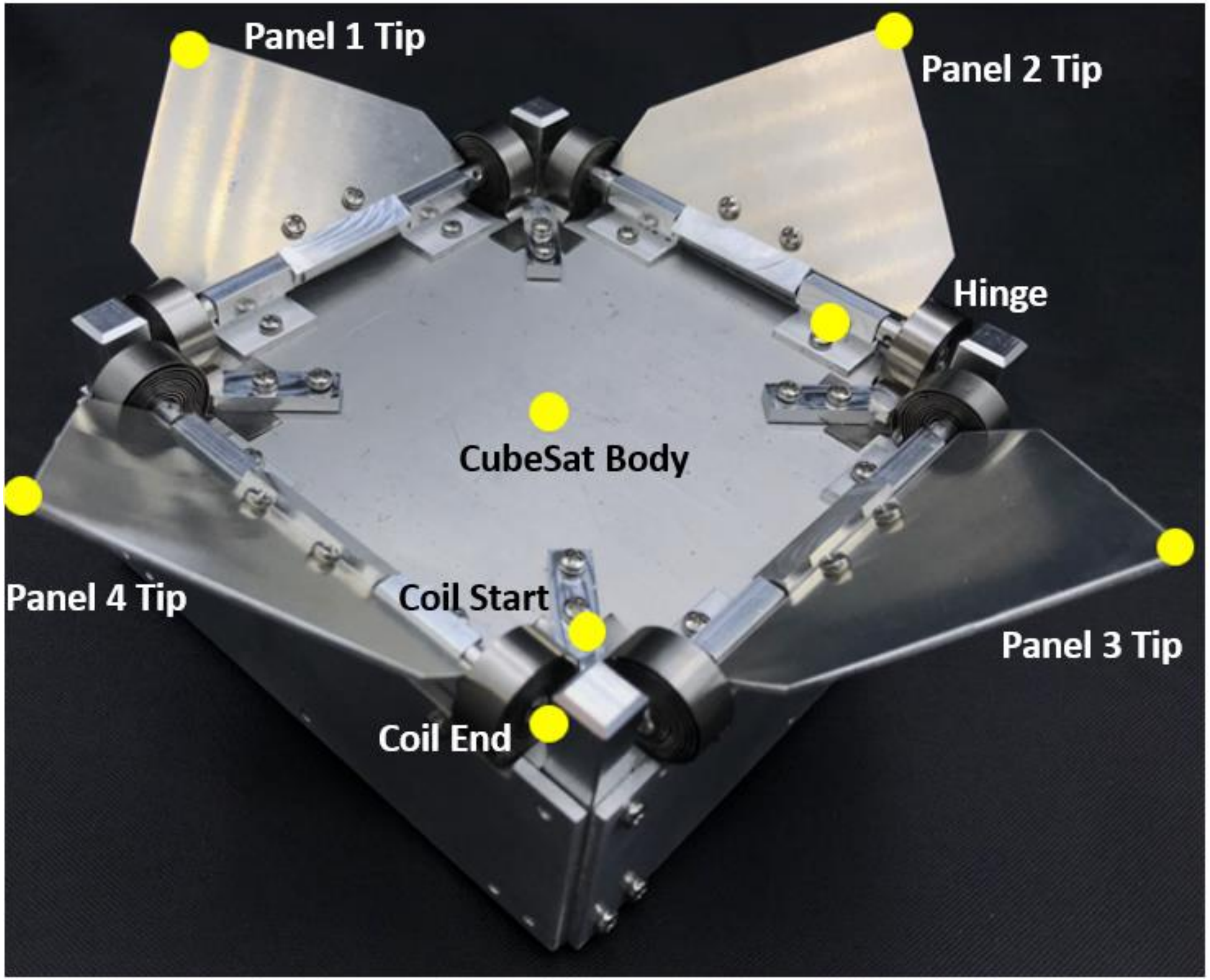
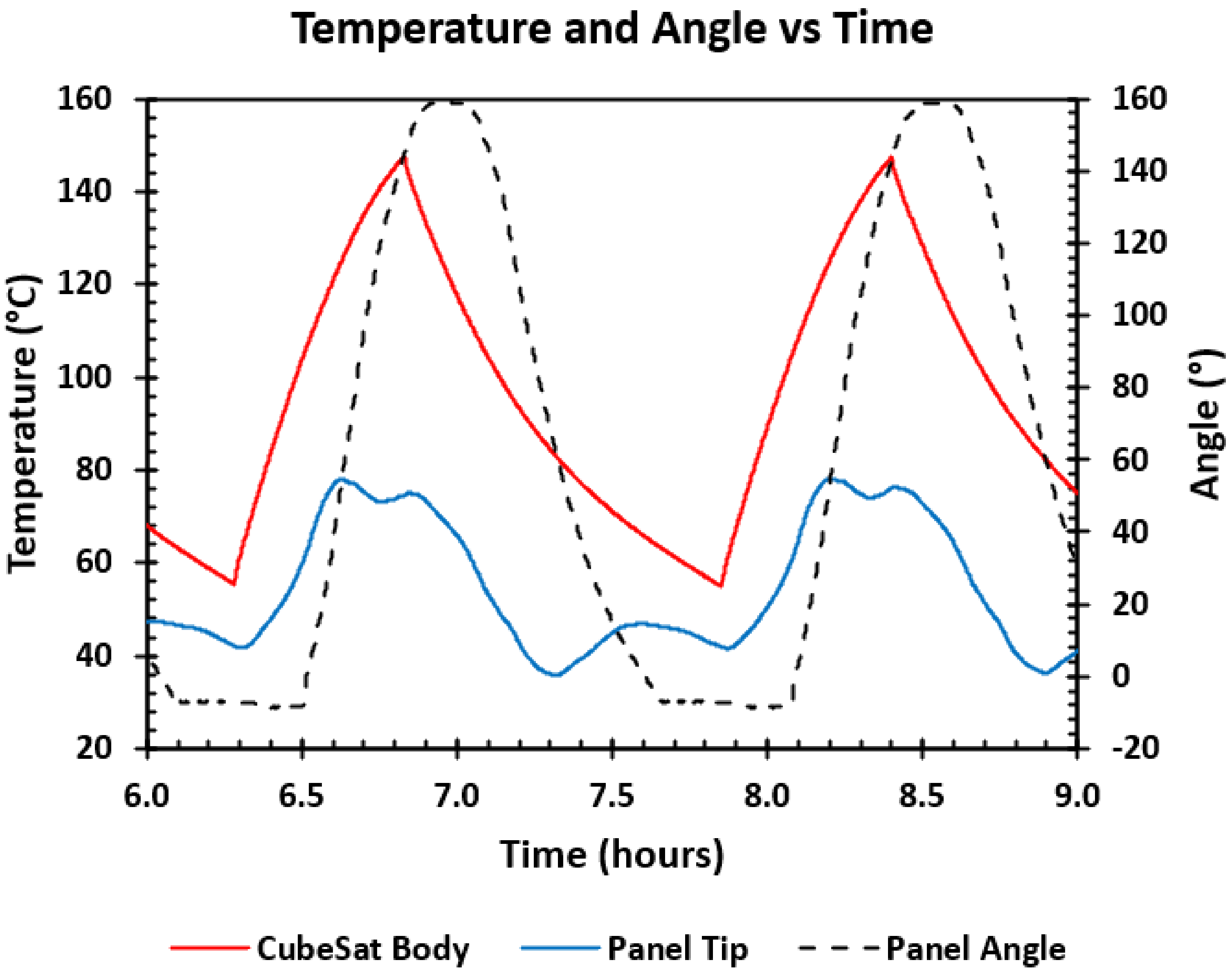
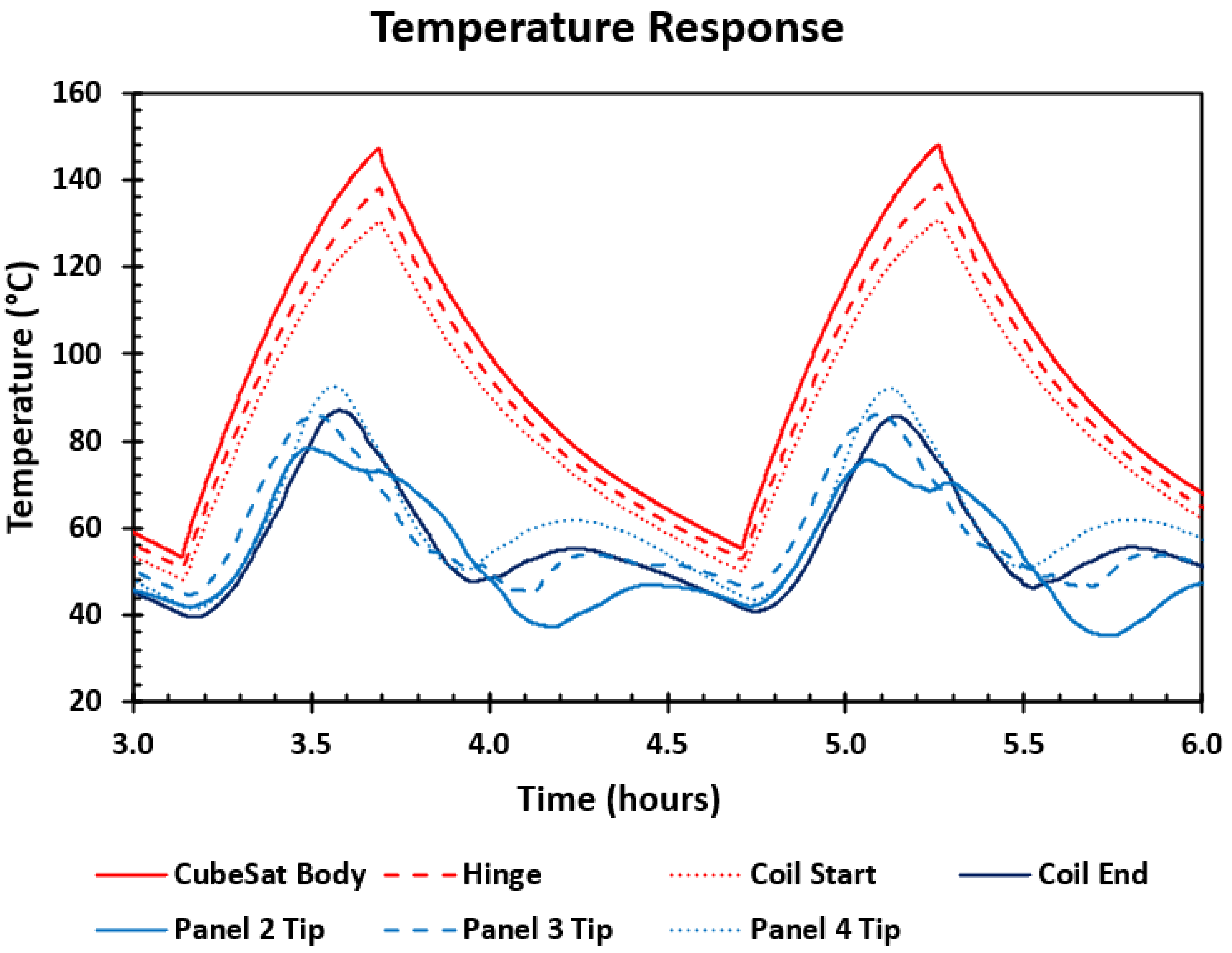


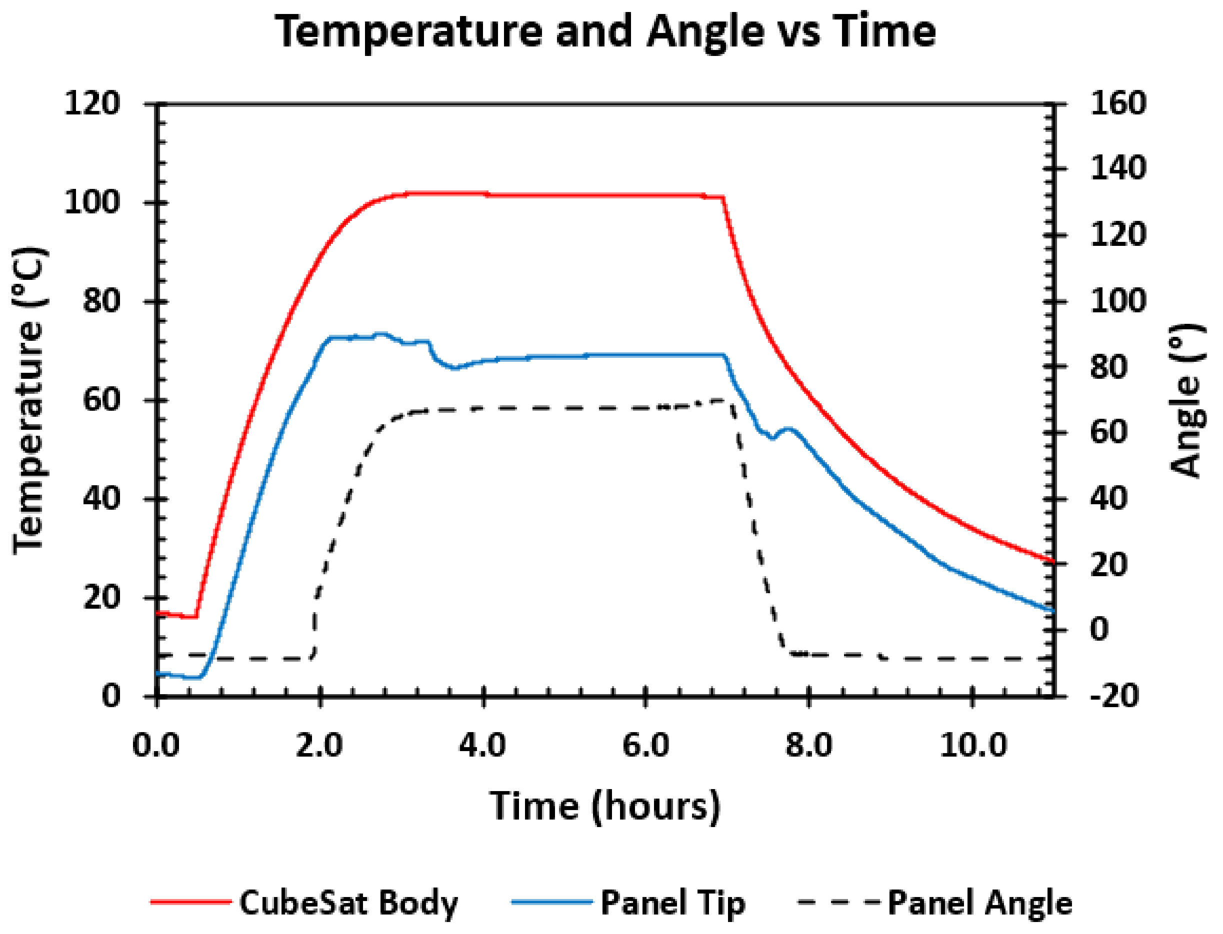
Testing Results

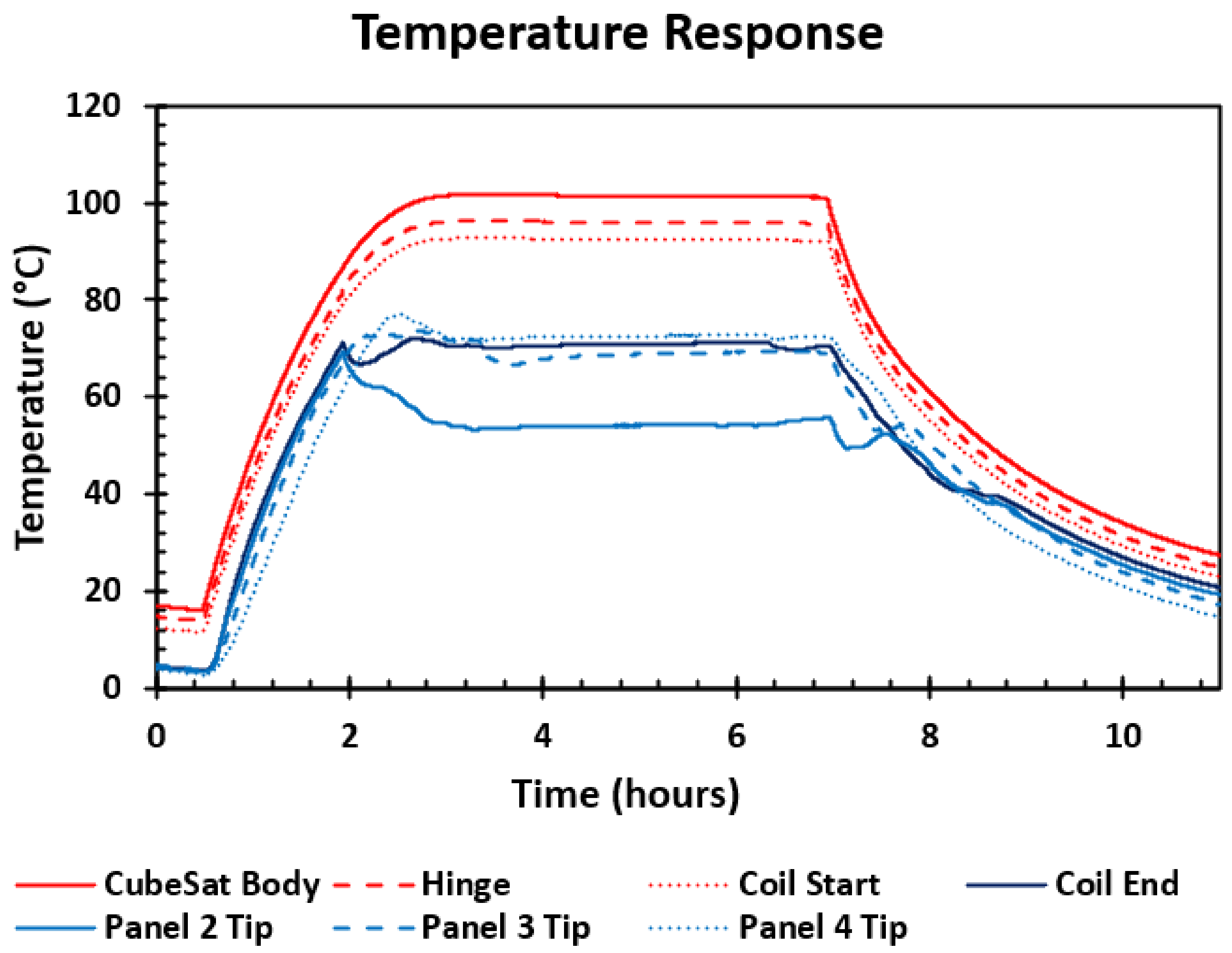


Testing Results



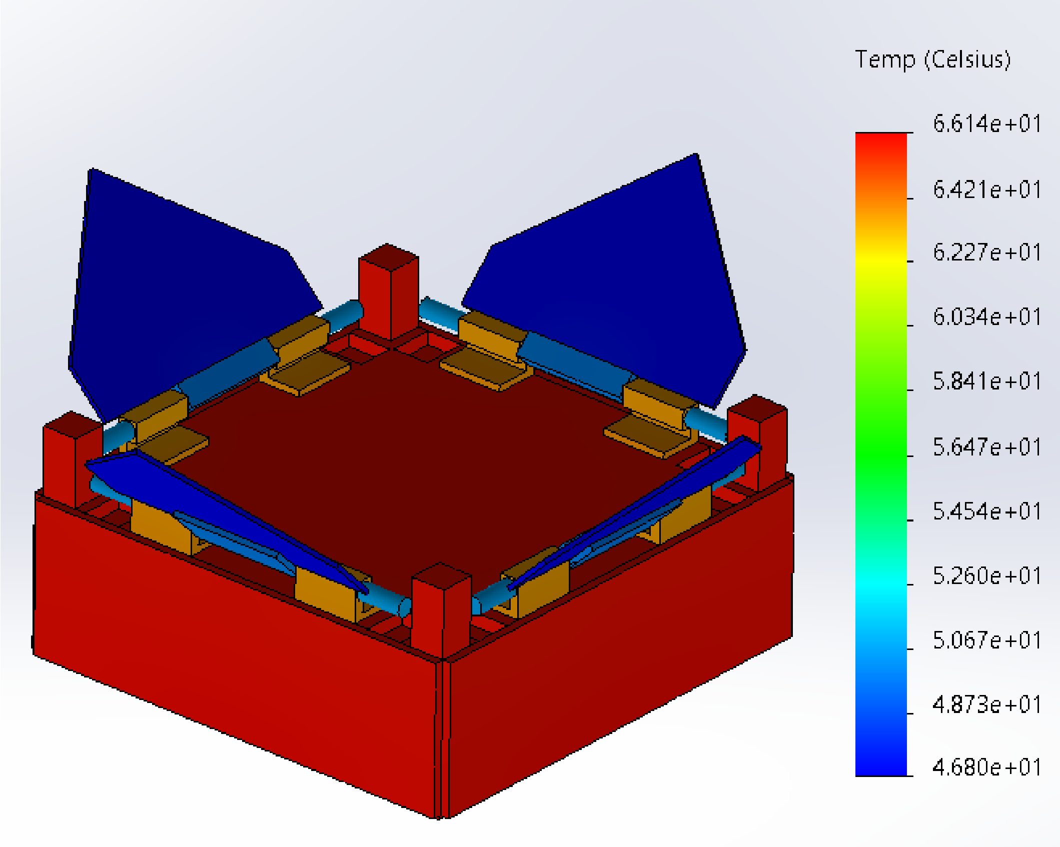
JPL Testing – Triangular Fin Results





Solidworks Thermal Simulation

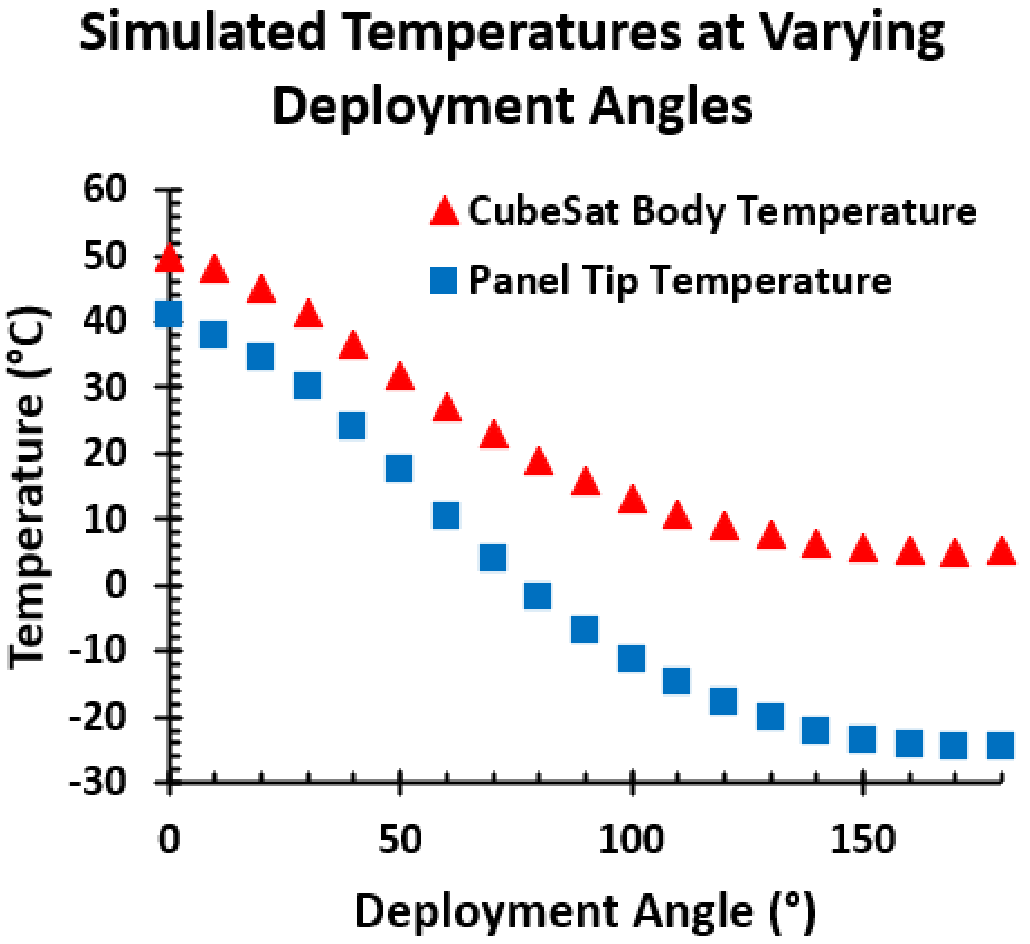
- Steady state, constant heat input tests were performed at BYU in an uncooled vacuum chamber
  - Objective was to obtain steady state temperature data for use in calibrating thermal model
- Thermal model built in Solidworks using known emissivities and conductivities
- 3 contact resistances were tuned
- Resulting agreement within 1 °C for both hot and cold steady state cases



	2.5 W		5 W	
	Measured (°C)	Simulated (°C)	Measured (°C)	Simulated (°C)
CubeSat Body	47.6	48.3	67.4	68.2
Hinge	46.4	47.1	65.2	65.9
Coil End	39.5	40.4	52.5	53.1
Panel Tip	38.4	38.1	48.4	48.8

Results

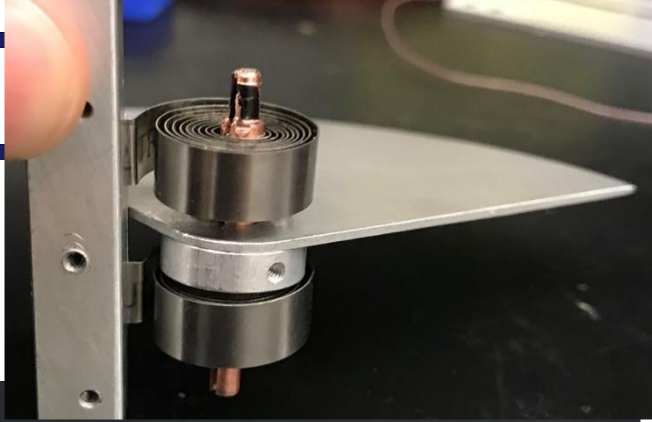
- Turndown ratio of 5,
  - 7-9 with improved contact resistances
- Deploying panels reduces CubeSat body temperature by about 50°C
- 15 minutes of phase lag
- Continuous states achievable

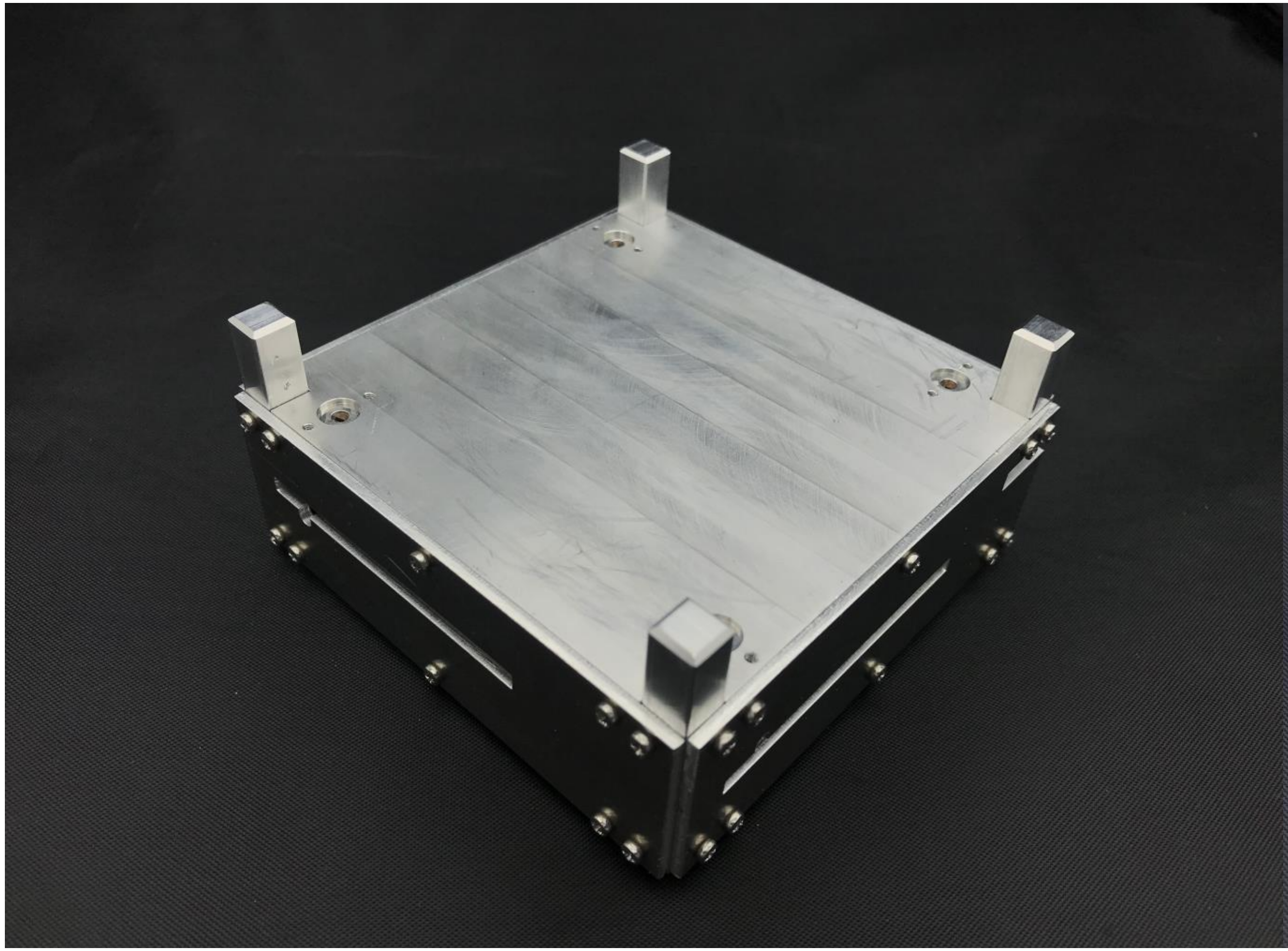


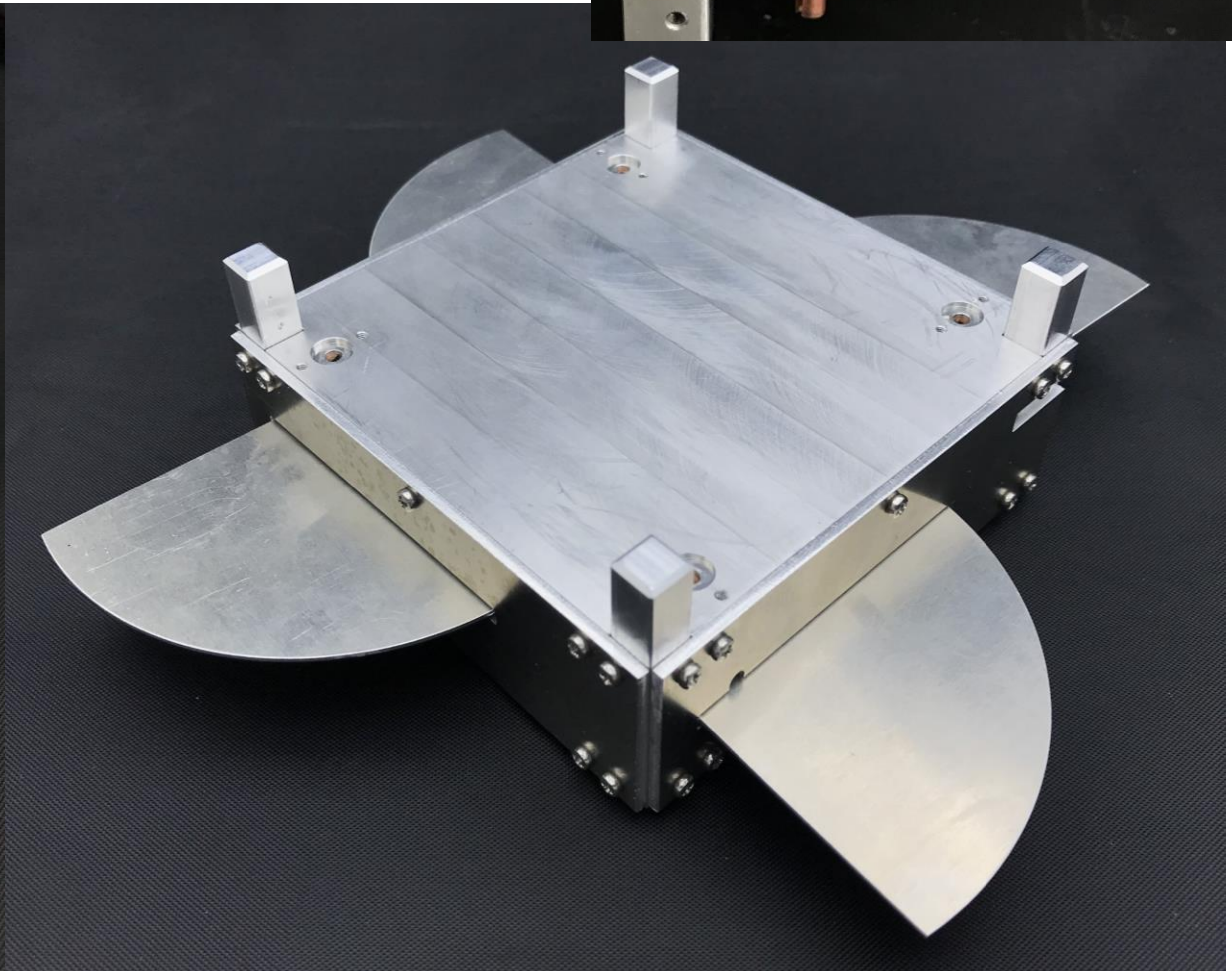
Future Work

- Improving conductive path to radiator fins
- Improving thermal connection between bimetallic coils and CubeSat body
- Thermal Desktop transient simulation
- Annular fin design

Annular Fin Unit







Acknowledgements

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References

1. Evans, A. (2019). Design and Testing of the CubeSat Form Factor Thermal Control Louvers. *Proceedings of the AIAA/USU Conference on Small Satellites, Technical Poster Session IV, SSC19-P4-23*. https://ntrs.nasa.gov/search.jsp?R=20190028943

2. Nagano, H., Ohnishi, A., Higuchi, K., & Nagasaka, Y. (2009). Experimental Investigation of a Passive Deployable/Stowable Radiator. *Journal of Spacecraft and Rockets - J SPACECRAFT ROCKET*, *46*, 185–190. https://doi.org/10.2514/1.30170