Evaluating the Performance Benefits of a Smart Radiator Device in Small Spacecraft Missions, for Earth Orbits and Beyond (SSC20-WP1-20)

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Introduction

A Smart Radiator Device (SRD) was developed by MPBC to meet the growing demand for advanced thermal control in smaller spacecraft. The SRDs exhibit a temperature-dependent emissivity profile due to the metal insulator phase transition of the thermochromic material of the coating. This results in a reduction in heat radiated from the spacecraft in low temperatures and consequently, a decrease in the power demand of heaters. We compared the expected performance of the SRD's to that of a traditional radiator through three simulated missions, with an emphasis on power and payload temperature swings.

Methods

We used NX Space Systems Thermal software to create thermal math models and spacecraft simulations under orbital and planetary heating loads. **Case 1 represents a CubeSat in Low Earth Orbit, Case 2 is a CubeSat in Geostationary orbit and Case 3 is a lunar lander payload on the surface of the moon**. The two orbital test cases used a single simulation for both sun and eclipse conditions. We obtained steady state results by running the spacecraft through multiple orbit cycles until the temperature change between cycles reached a convergence threshold. Due to a longer timeline in the lunar lander case we used two separate simulations, one simulation for day time and one for night time (eclipse).

All simulations are based on the same original spacecraft model, a 3U CubeSat design being developed by STARLab. The orbiter model is very similar to the original CubeSat design, while major changes were made to the lunar lander model to reflect a lunar lander payload. The size of the lunar lander spacecraft was reduced to a 1U module, to represent a form factor more appropriate as a rover payload and to reduce computational efforts during the long eclipse run time. We also modelled a multi-layer insulation (MLI) blanket around the spacecraft to minimize the radiative heat transfer with the variable lunar environment. Figure 1 shows the CAD model of the orbiter spacecraft, Figure 2 shows the lunar lander CAD model without the MLI, and the lunar lander with MLI. We ran each simulation case twice, once with radiator panels of traditional radiator emissivity and again with the temperature dependent emissivity of the SRDs.

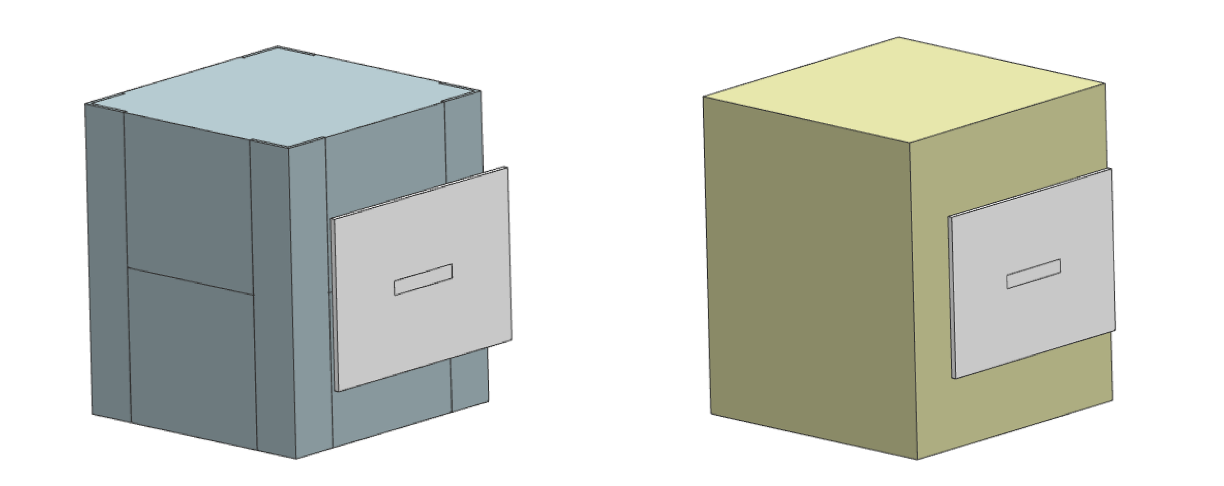

Figure 2: Lunar lander CAD model without the MLI (Left), lunar lander with MLI (Right)

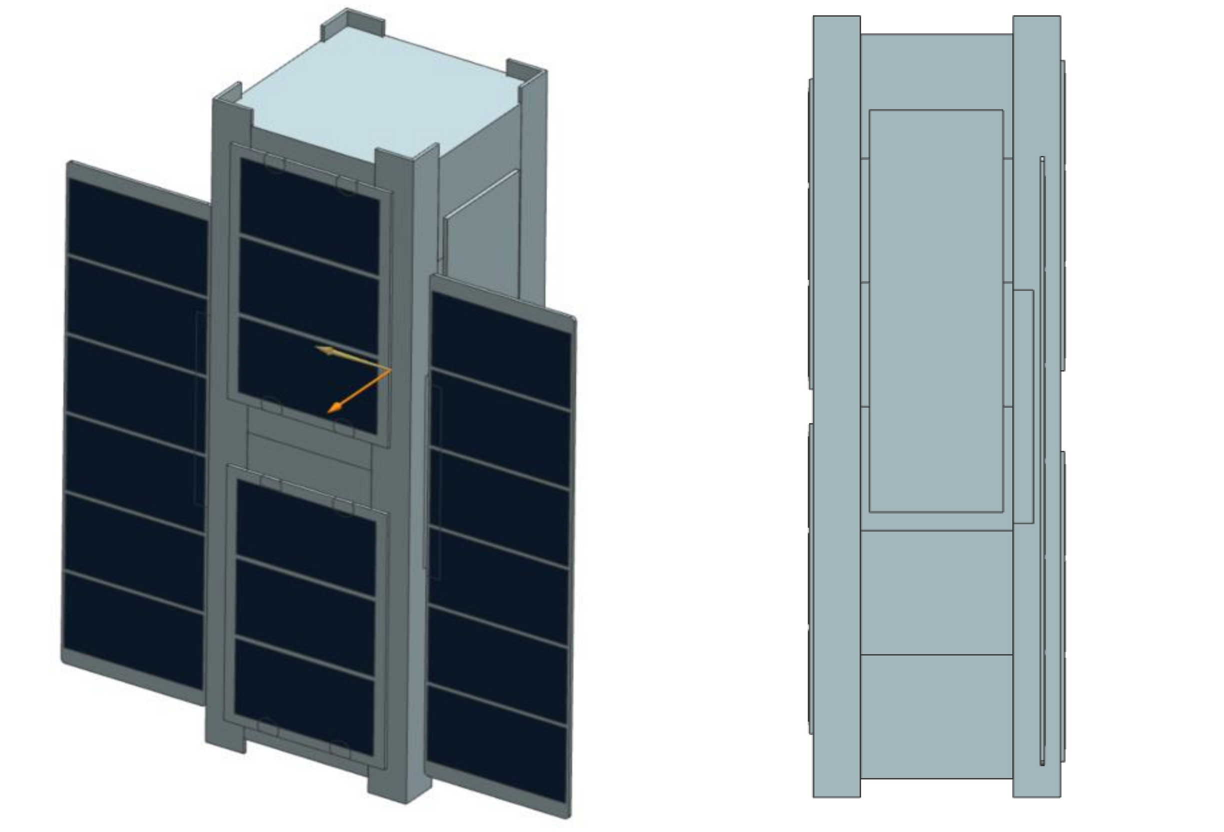

Figure 1: Orbiter spacecraft CAD model

Results

Case :	1		2		3-Daytime		3-Night time	
	CubeSat in LEO		CubeSat in GEO		Lunar Lander		Lunar Lander	
	SRDs	Radiator	SRDs	Radiator	SRDs	Radiator	SRDs	Radiator
Heater time on (s)	295.5 s	747.4 s	2358.2 s	2930.4 s	2935.7 s	4325.7 s	1995.8 s	2812.3 s
Heater total energy (J)	886.4 J	2242.0 J	35373.9 J	43960.7 J	1679.5 J	5357.7 J	29946.6 J	42131.5 J

SRD Development

The SRD technology is currently in the prototyping and development phase. MPB has identified a number of target improvements to the SRD properties and production to allow the technology to be mass produced and commercially sold. Developments in the manufacturing process include improving reproducibility and autonomy, and increasing SRD size. Improvements to the solar absorptance, the low and high temperature emissivity, and the substrate processing temperature are currently under investigation.

Conclusion

The results of the simulations show that the SRDs exhibited heater power savings for all simulation cases. The highest power savings occur for the lunar lander day simulations, where the payload must be kept at operating temperatures while the radiator is rejecting heat constantly out to deep space. In this case, **219%** more energy was required for the traditional radiator spacecraft. In the nighttime lunar lander simulation, **41%** more energy was required when using the traditional radiator. The LEO simulation results in **153%** more energy consumption when using the traditional radiator, and the GEO simulation showed a **24%** increase in energy demand over the SRDs spacecraft. As is supported by these results, the ideal usage case for the SRDs is when the variation in heat loads from hot to cold are very high, either due to internal or external loading. The SRD is still under development, but these results show the technology can be competitive with other commercial radiators and provide considerable benefits.