

Enhanced Phase Change Material for Satellite Thermal Regulation

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Abstract:

Electronics on satellites need to operate within an optimum temperature range. Since temperature fluctuates widely in space, thermal regulation devices are crucial to maintain the optimal temperature on board. This project focuses on the application of phase change materials (PCM) for satellite thermal management. As compared to electric heaters and radiators, PCM are highly attractive because they can be applied as **passive** thermal management systems(TMS) that **do not consume power**.

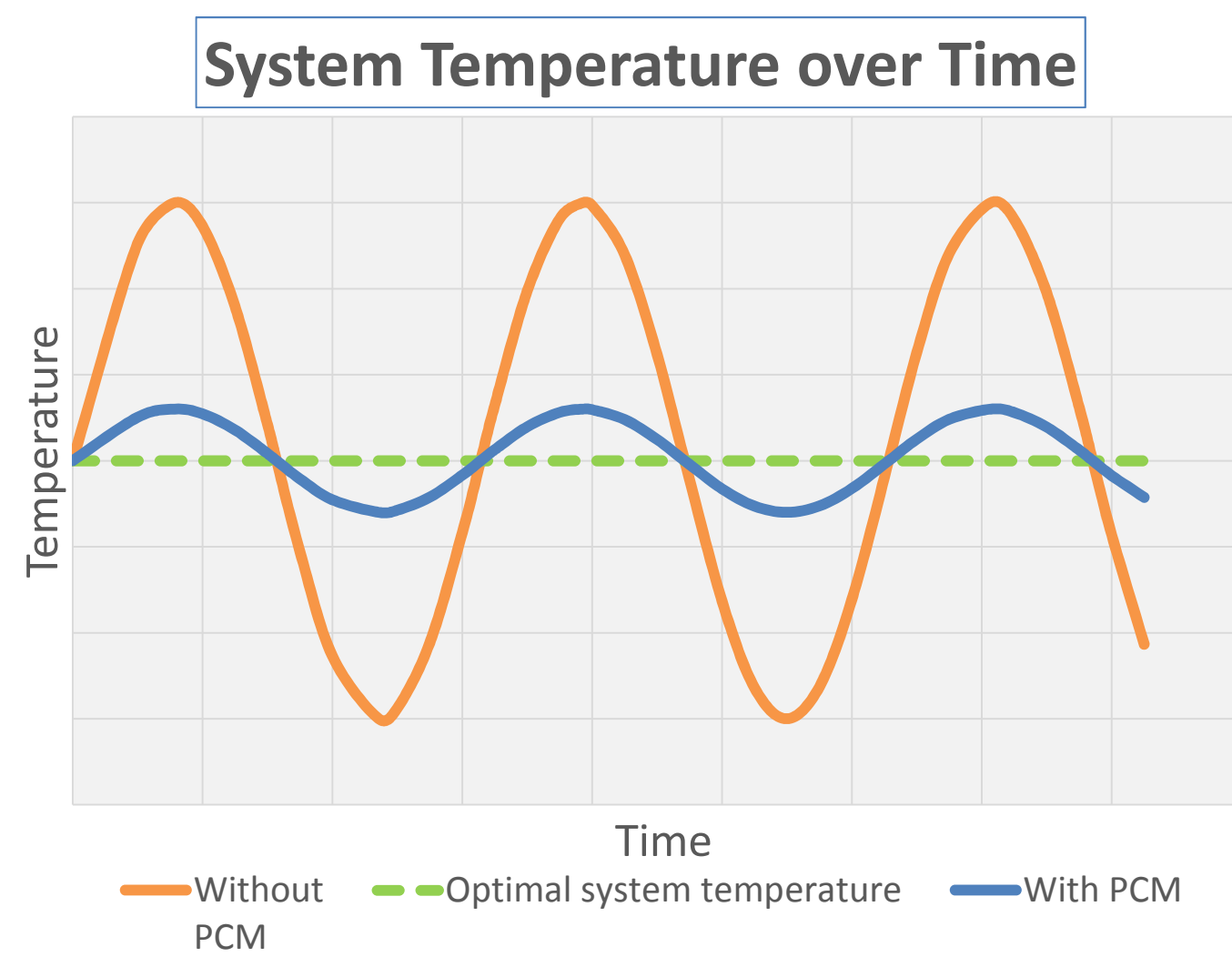
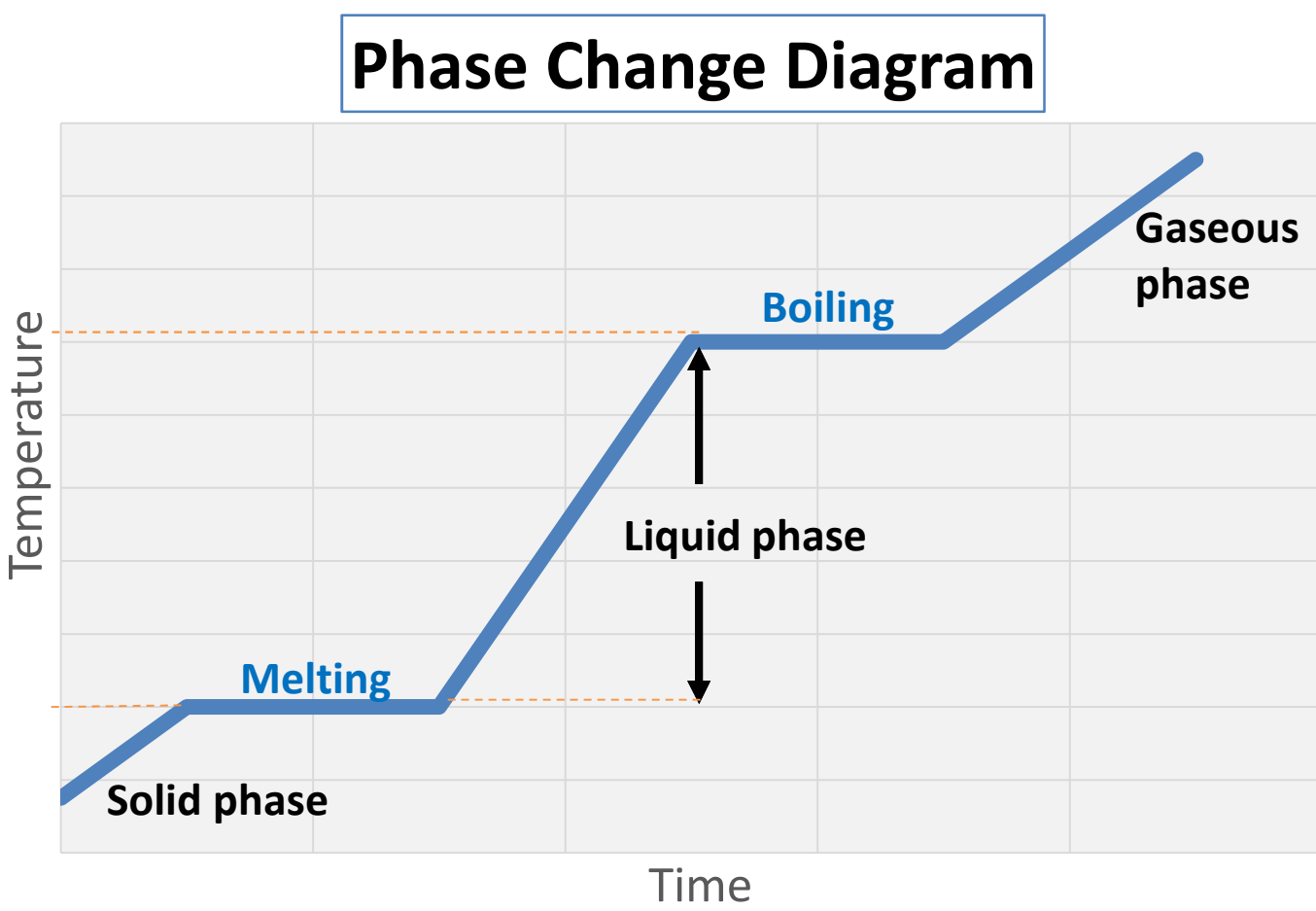
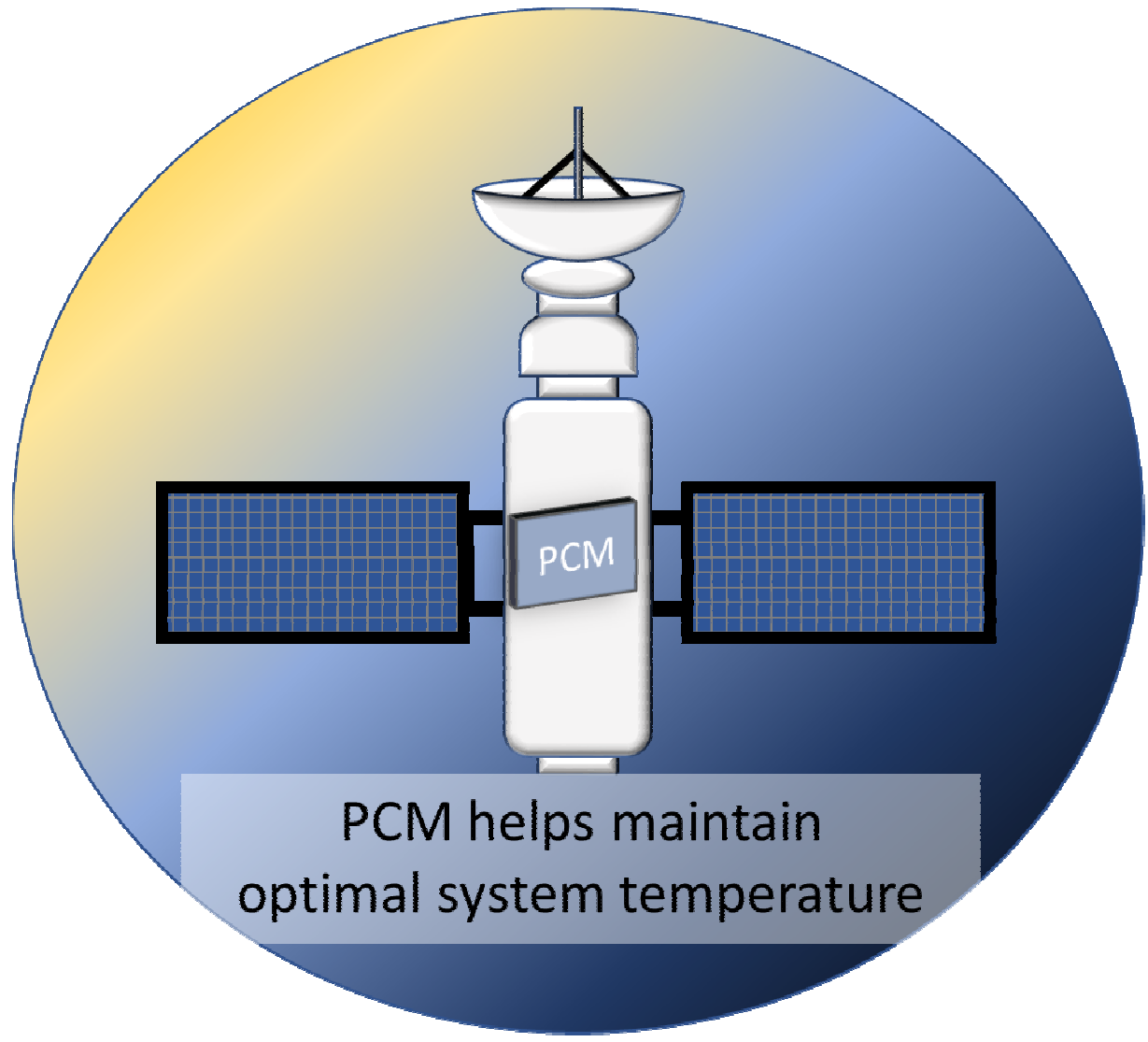
Introduction:

PCM are substances that absorb and release large amount of latent thermal energy during phase change while maintaining a constant temperature. Such heat can be utilized to regulate temperatures in the vicinity. This helps control large temperature fluctuations experienced by a satellite in orbit. PCM also boasts thermal cycling stability, non-corrosiveness and low outgassing. Thus PCM have high potential to be applied as part of any satellite thermal regulation system.

However, PCM are limited by their low thermal conductivity. This results in slow, localized heating which reduces efficiency and under-utilizes their latent energy storage. To overcome this limitation, three dimensional nanomaterial foam (3D-C) is chosen as a suitable substrate for PCM in this project.

Project Objectives:

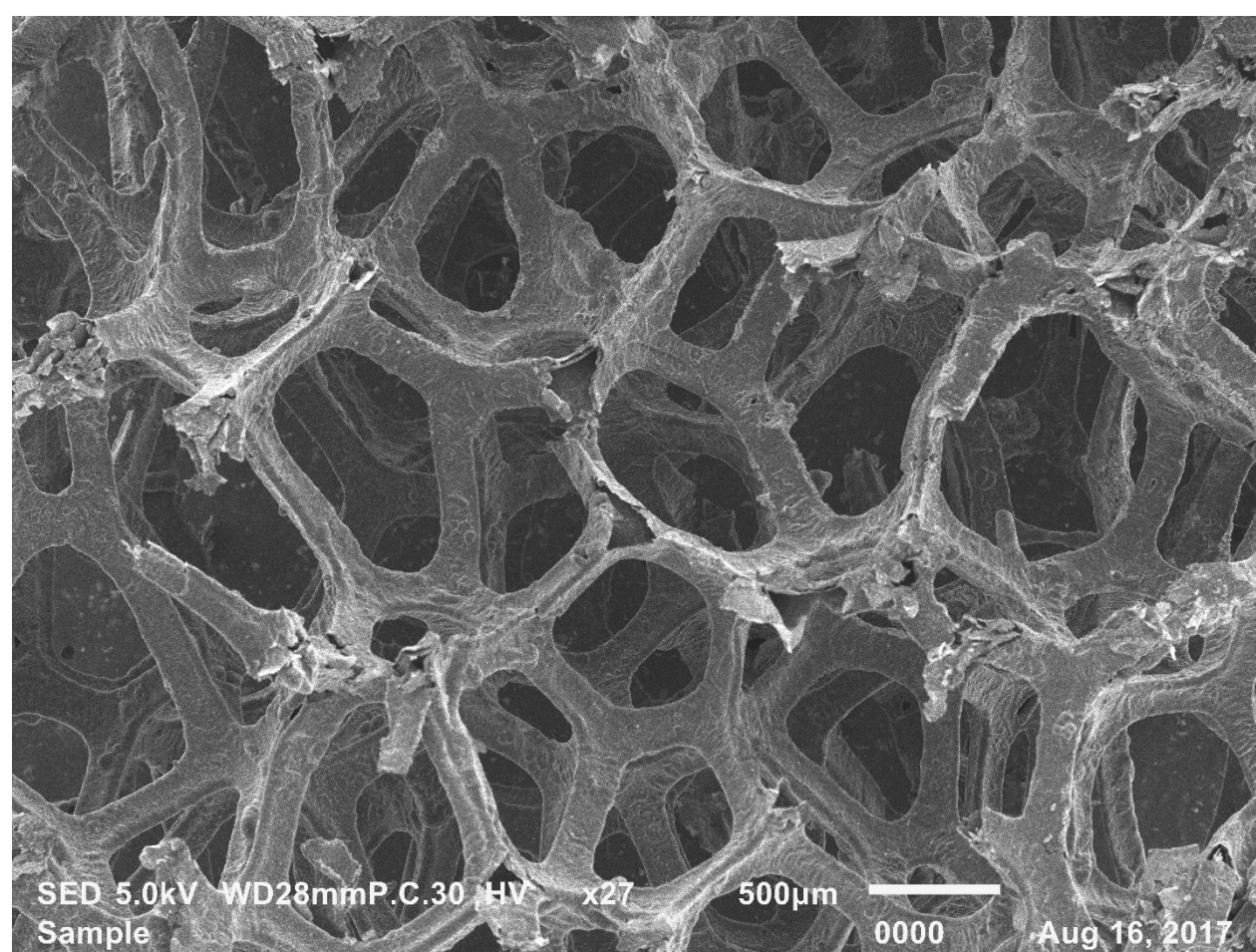
Design and develop 3D-C enhanced PCM composites with **good thermal storage properties** and **high thermal conductivity**, as innovative solution for efficient passive TMS for small satellites.



Paraffin wax PCM



Nanomaterial Foam: **3D-C**



SEM of 3D-C strut network



Nanomaterial enhanced paraffin composite

Key Differentiators:

- **Interconnected 3D-C struts network** provides thermal highway to effectively spread thermal energy throughout the PCM
- 3D-C is **light-weight** and has **high porosity** (>99%)
- Nanomaterial-enhanced paraffin composite has the combination of:
 - improved **thermal conductivity**
 - negligible compromise on **thermal storage properties** (e.g. Latent heat, heat capacity)
 - consumes **no power** (passive TMS)

Developmental Works:

- Application and tests of thermal properties for specific cases, provided **Thales Alenia Space** (TAS).
- Space Qualification of PCM composite.
- Study of thermal interfacing between PCM and filler material

S/N	Sample description	Thermal Conductivity (W/m·K)	Latent Heat of Fusion (kJ/kg)
1.	Paraffin wax	0.24	200.7
2.	Paraffin with 3D-C	2.11	186.9

Table 1: Property improvement after 3D-C infusion

Potential Benefits:

- Improved **efficiency** in thermal regulation
- **Weight** optimization
- Complements current TMS

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