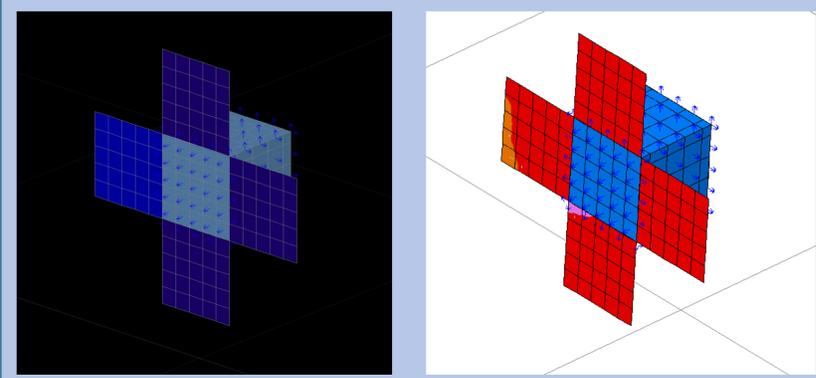


Motivation & Objectives

Variably emissive materials exhibit the ability to change their radiative properties depending on certain environmental stimuli [1-2]. This can be through either a change in temperature (thermochromic) or by an applied voltage (electrochromic). These materials can be developed as coatings, and this project seeks to study the applications of a well researched phase change material (Vanadium Dioxide) as opposed to conventionally used white paint. This coating is applied the radiators of a 1U Cubic Satellite. The satellite has 4 solar arrays of PV module laminate [3]. Three cases are observed: a low Earth orbit (LEO) case at a 400 km altitude, a lunar transit (deep space) case, and low lunar orbit (LLO) case at 100 km.

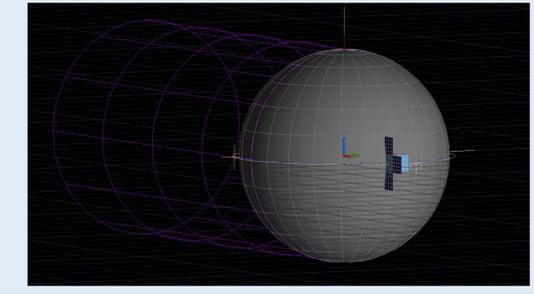
Results: Lunar Transit



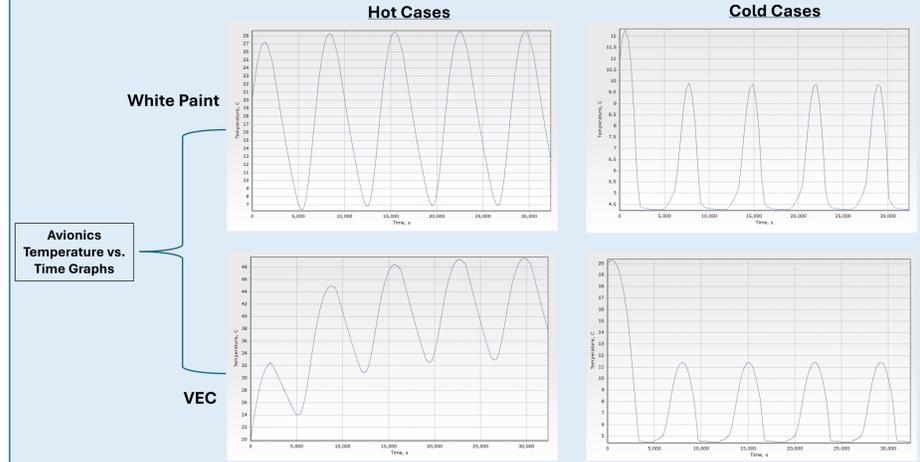
Heater Power (W)	
White Paint	9.584
VEC	4.075

In the lunar transit case, the avionics heater becomes vital to the survival of the CubeSat. In comparison to the white paint optics on the radiators, the VEC material uses 5 watts less heater power to stabilize and reach a target temperature of 40 °C, making it a more efficient radiator coating in terms of conserving power.

Results: Low Lunar Orbit (LLO)



Heater Power (W)	
White Paint	6.9369
VEC	3.443



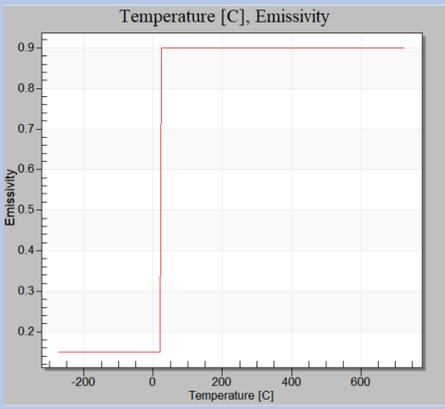
References

- [1] Taylor, S., Yang, Y., Wang, L. (2017). Vanadium dioxide based Fabry-Perot emitter for dynamic radiative cooling applications. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 197, 76-83.
- [2] Taylor, S., Long, L., McBurney, R., Sabbaghi, P., Chao, J., Wang, L. (2020). Spectrally-selective vanadium dioxide based tunable metafilm emitter dynamic radiative cooling. *Solar Energy Materials and Solar Cells* 217, 110739.
- [3] Lamaamar, I., Tilioua, A., Hamdi Alaoui, M. A. (2022). Thermal performance analysis of a poly-c-Si PV module under semi-arid conditions. *Materials Science for Energy Technologies*, 5, 243-251.
- [4] NASA CubeSat Launch Initiative (2017). *CubeSat 101: Basic Concepts and Processes for First-Time CubeSat Developers*.

Methodology

Material	Thermo-Physical Properties		
	Conduction $\left(\frac{W}{m \cdot K}\right)$	Density $\left(\frac{kg}{m^3}\right)$	Specific Heat Capacity (c_p) $\left(\frac{J}{kg \cdot K}\right)$
Aluminum 6061	167	2702	900
Photovoltaic (PV) Components	Glass	3000	500
	EVA	0.35	2090
	Polycrystalline Silicon	148	2330
	TEDLAR	0.2	677
PV Module Laminate	ANISO.	2506.4	624.03

Material	Optical Properties	
	Solar Absorptivity (α)	Emissivity (ϵ)
White Paint	0.150	0.900
VEC	0.200	Temperature Dependent



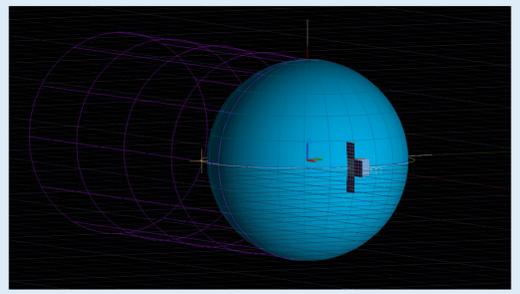
In the graph to the left, the emissivity for the VEC is shown. Since the metal-to-insulator phase change is dependent on the temperature, the VEC experiences an emissivity change of 0.75 in the range of 19-25 °C. At the insulator phase (< 19 °C), the emissivity is 0.15, and at the metal phase (25 °C), the emissivity stabilizes at 0.90.

Key Performance Parameters (KPP)			
CubeSat Dimensions: 1U (10 cm x 10 cm x 10 cm)			
Solar Panel Tilt: 0°			
Body	Earth		Lunar
	Altitude	400 km (LEO)	100 km (LLO)
Orbit	Beta Angle	0°	0°
	Facing	Velocity Vector/Nadir	Velocity Vector/Nadir
	Solar Flux	1367 $\frac{W}{m^2}$	1426 $\frac{W}{m^2}$
	Albedo	0.3	0.15
IR Planetshine	265 $\frac{W}{m^2}$	Varies	

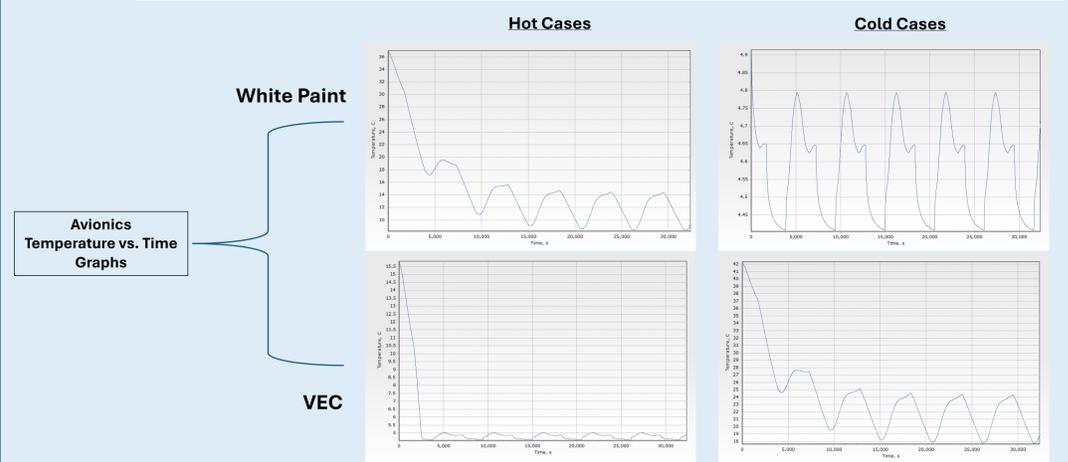
```

FORTRAN Code for Dynamic SINDA
IF (NSOL .EQ. 0) THEN
C  WRITE('**callingdynamicsinda'
CALL DUMPT('temps.out',0)
CALL TDUPDATE
CALL TDCASE
LastAVTemp=AVT1
ENDIF
IF (NSOL .EQ. 0) THEN
C  WRITE('**callingdynamicsinda'
CALL DUMPT('temps.out',0)
CALL TDUPDATE
CALL TDCASE
LastAVTemp=AVT1
ENDIF
IF (abs(AVT1 - LastAVTemp .GT. 5.)) THEN
C  WRITE('**callingdynamicsinda'
CALL DUMPT('temps.out',0)
CALL TDUPDATE
CALL TDCASE
ENDIF
  
```

Results: Low Earth Orbit (LEO)

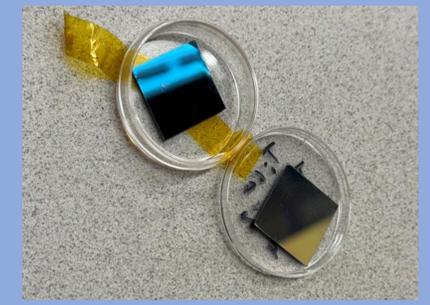
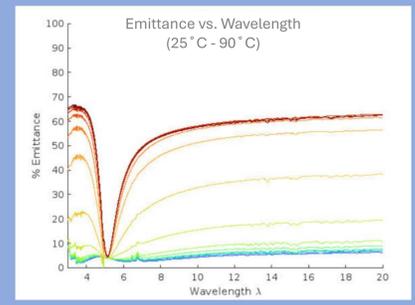


Heater Power (W)	
White Paint	8.475
VEC	3.987



Ongoing & Future Work

Although it is valuable to see the performance of these VECs on a small spacecraft such as a 1U CubeSat, future work is desired in modeling these coatings on a larger scale, such as on a 6U or even 12U CubeSat. The state of the art also has its own short comings, with transition temperatures being too high, absorptivity being too high and emissivity being too low, and even large-scale production. This project seeks to improve on these short comings, either through different manufacturing methods or modeling of previously unknown materials.



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