A Thermal Analysis of a 6U CubeSat

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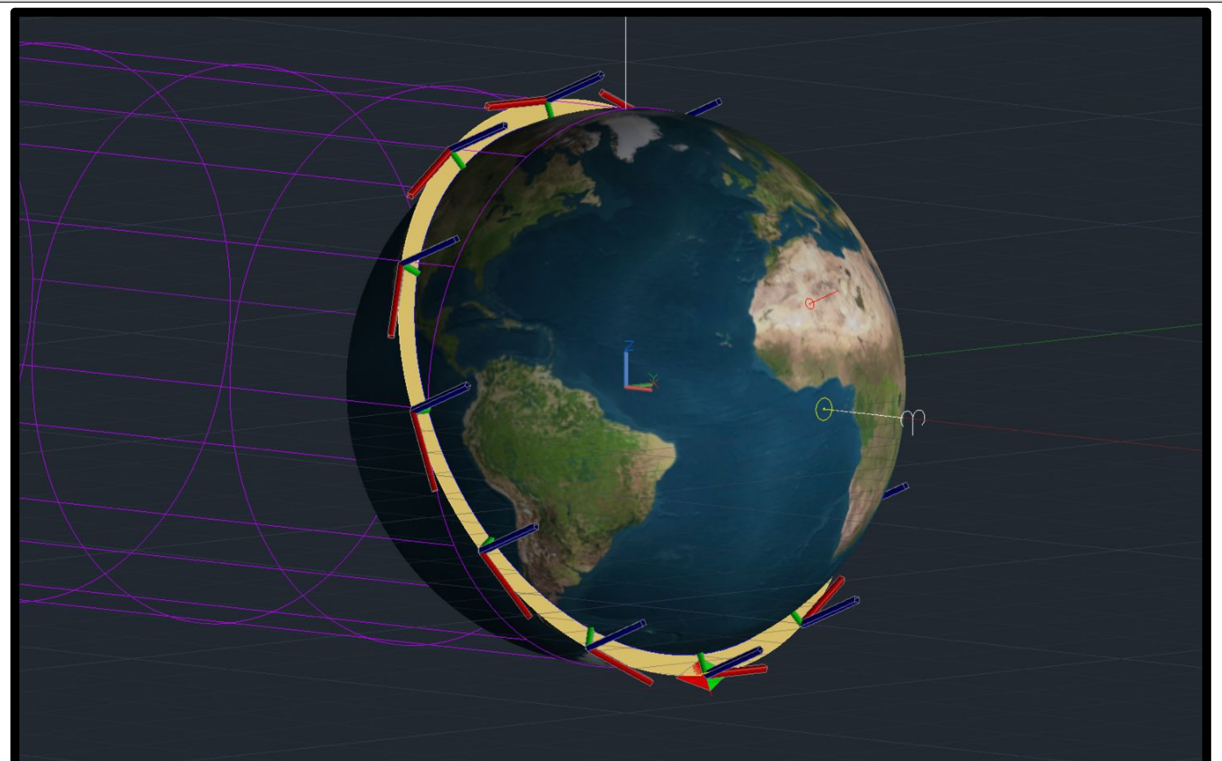
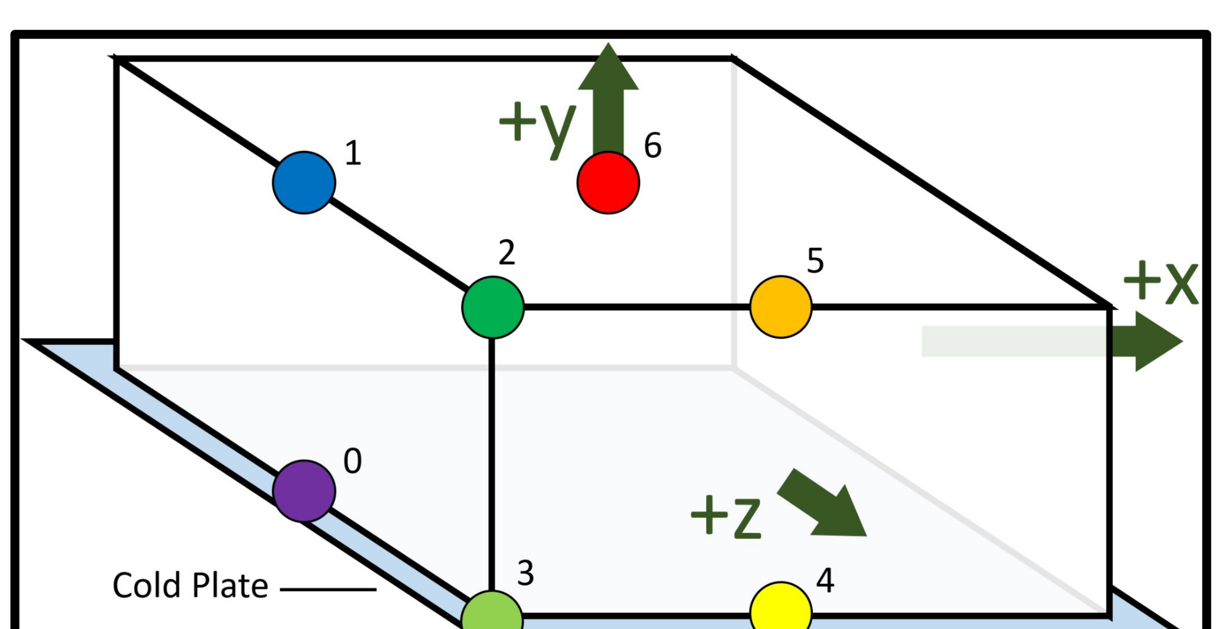


A L.E.O. Orbit with Beta Angle = 68.1°

Abstract: With no convection, orbital spacecraft temperatures can reach extreme highs and lows. The stability of craft temperature is critical for continued hardware functionality. **Creation of a thermal model allowed for the examination of temperature stability from the environment and surface coating choice.** Lab tests confirmed the efficacy of using a mylar-based insulation, along with including a thermal control system, to achieve temperature stability.

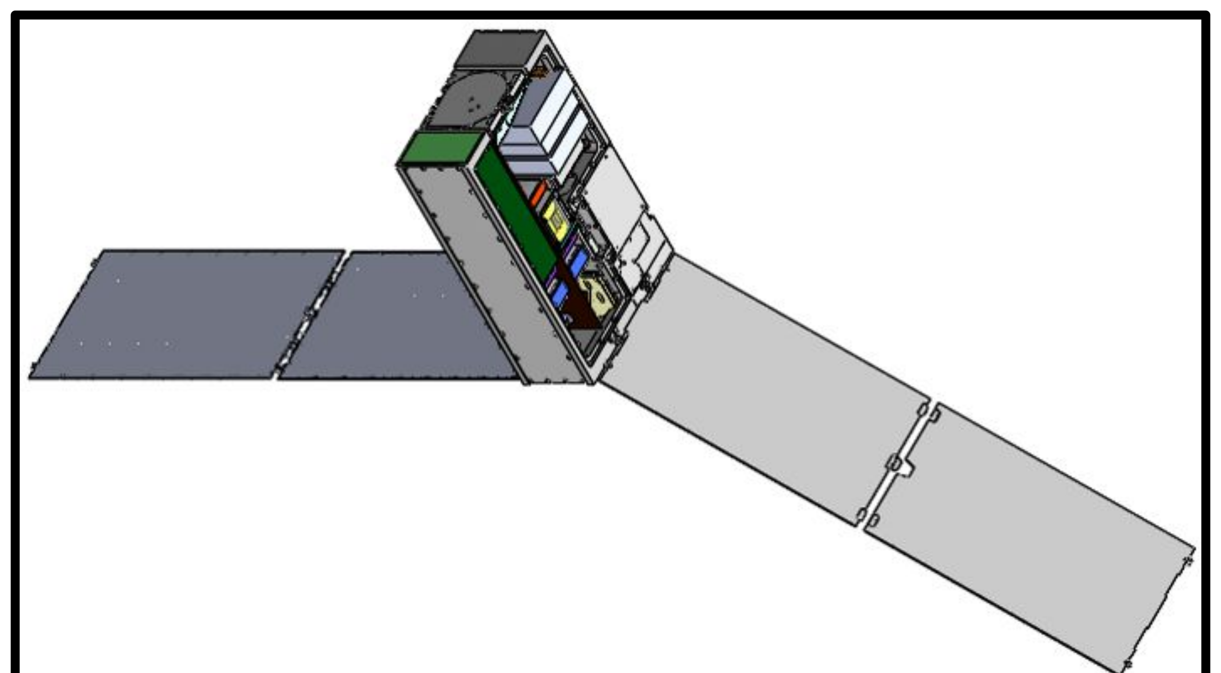
Description: A six node model created in MATLAB, the AutoCAD package "Thermal Desktop", and vacuum chamber testing were used to identify and confirm the thermal behavior of the CubeSat and the influence of coating materials and internal heat on the temperature stability of the payload.



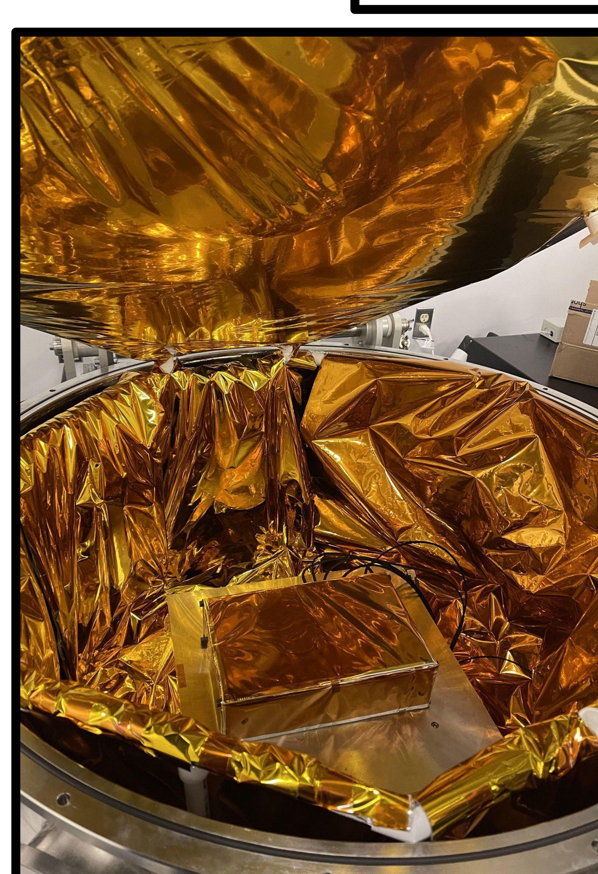
Temperature Sensor Placement on 6U Chassis

Purpose & Goals:

- Create and verify thermal models
- Determine influence of different heating sources on steady-state temperatures.
- Select surface coating material(s) to maintain temperature between 5-25℃
- Stabilize payload temperature to vary by less than 0.1℃

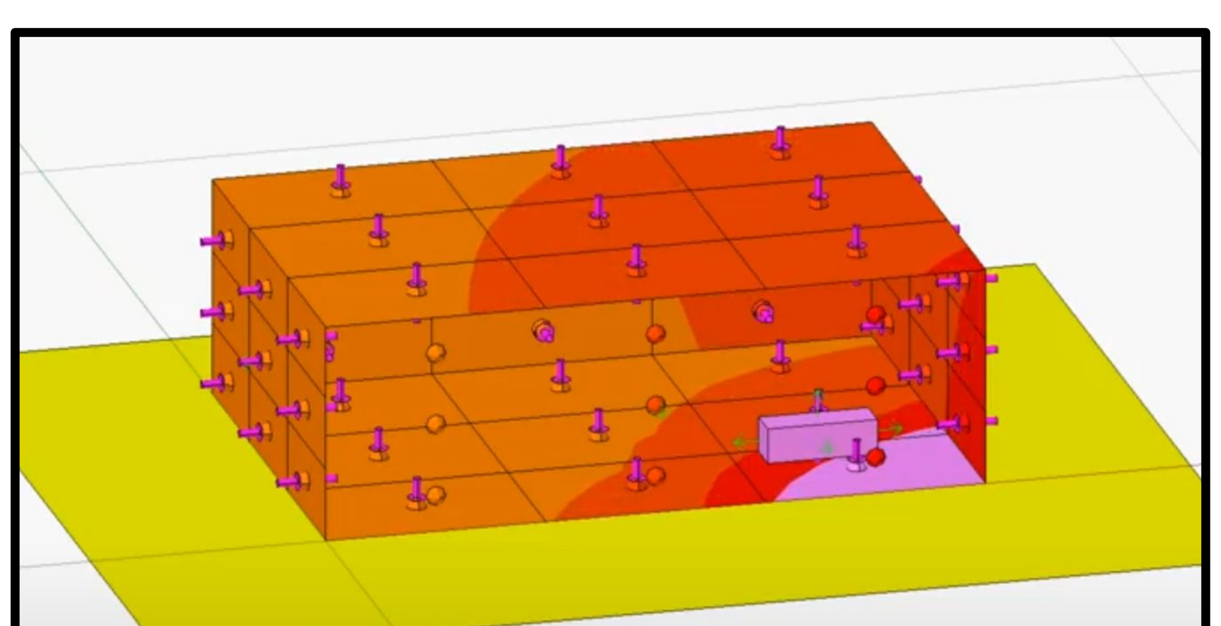


3D Render WindCube



6U Chassis in Chamber

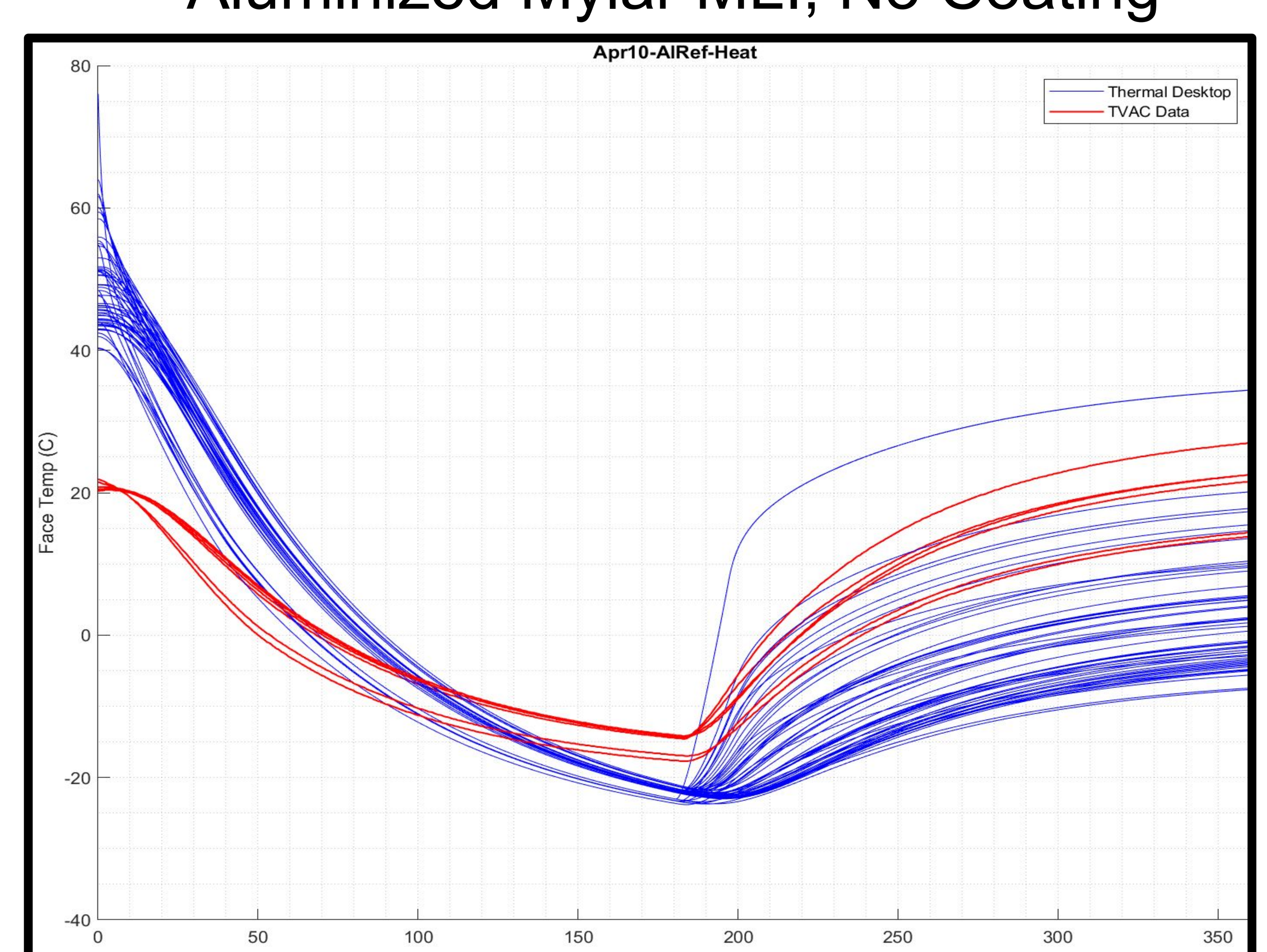
HAO Vacuum Chamber



Recreated Vacuum Chamber in Thermal Desktop

Methods:

- Six-Node MATLAB Model
  - Used to generate a fundamental understanding of the baseline orbital thermal environment.
  - Aides in identifying necessary materials and design requirements to assess the thermal behavior of the spacecraft.
- Thermal Desktop Model
  - Specializes in rapid testing of all orbital angles, surface coatings, and internal heating conditions
  - Used for direct recreation of TVAC environment for validation
- Thermal Vacuum Chamber Model
  - Generates real-world data to verify accuracy of computer models.
  - Testing setup:
    - 6U chassis placed on cold plate with swappable coated panels
    - 7 temp sensors + plotting software
    - 20℃–35℃ range, -2℃/min ramp
- Surface Coatings:
  - White Paint, Black Paint, Aluminized Mylar MLI, No Coating



Bare Al + Heat Tests, TD (Blue) & TVAC (Red)

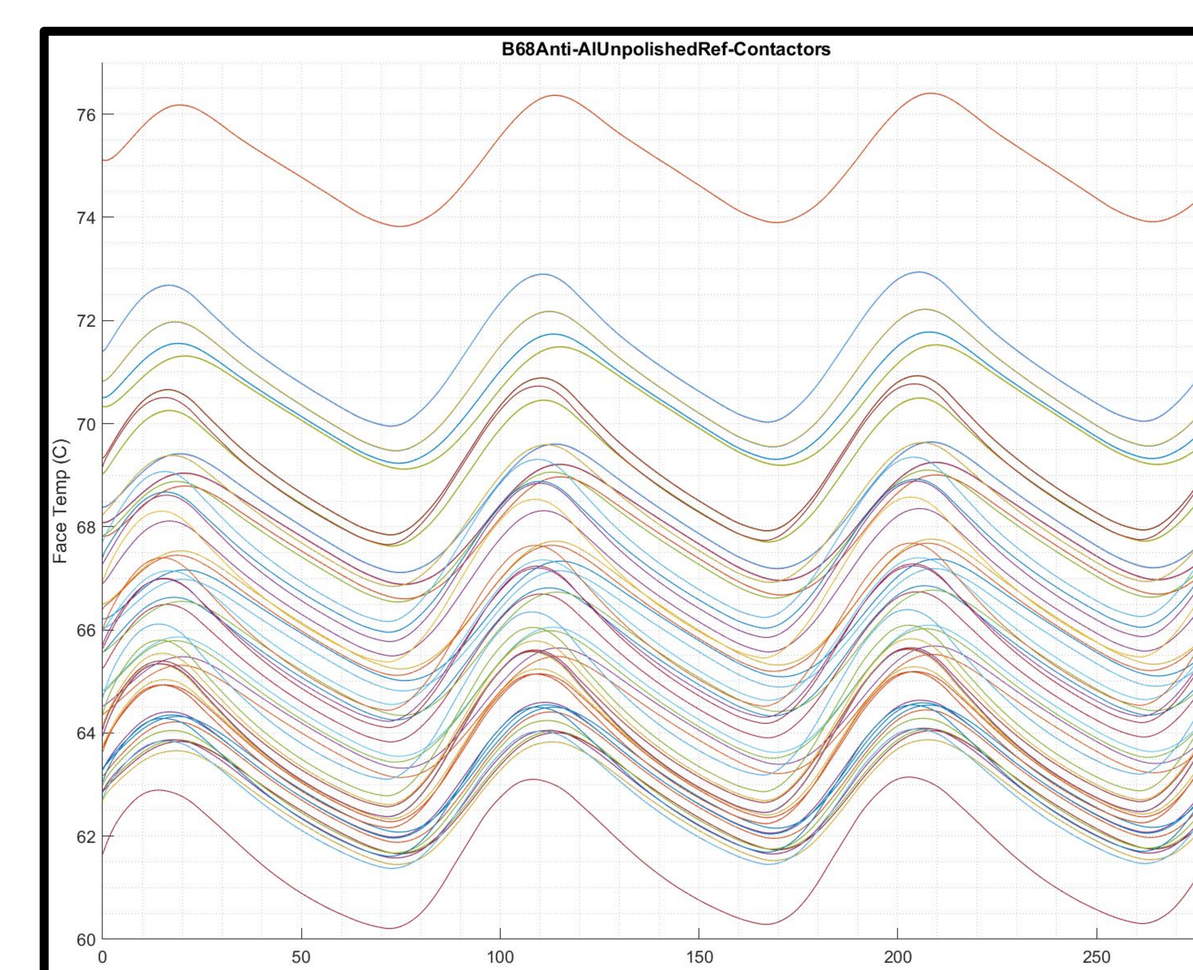
Results

Material	Ratio α/ε	Mean Temp (℃)	Face Temp Range (℃)
Mylar MLI	0.34	-54.4	7.2
No Coating	0.3077	-59.8	9.4
White Paint	0.2684	-67.0	12.9
Black Paint	1.1156	20.5	40.4

Spacecraft temperatures heavily depend on the following:

1. The Surface Coating Material
   - The ratio between absorptivity and emissivity values of the material
2. Heat Output of Internal Heat Sources
   - On-board general avionics and payload instruments
3. The Orbital Parameters
   - The Beta angle, depends on inclination and right ascension of the ascending node

Conclusion: From this thermal analysis, the team recommends a **mylar-based insulation** along with including a high-level thermal control system to achieve temperature stability of the etalon and focal plane array of WindCube's on-board interferometer.



Simulated Orbital Temperatures, Beta Angle 68.1°

MCEN 5065/5075: Graduate Project Design, Design Center Colorado - Department of Mechanical Engineering | High Altitude Observatory, University Corporation for Atmospheric Research - National Center for Atmospheric Research